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THE SABINE UPLIFT, LOUISIANA

SIDNEY POWERS

INTRODUCTION

The Sabine Uplift is an area approximately eighty miles long and sixty-five miles in maximum width, situated in the northwestern corner of Louisiana and in the adjacent portion of Texas. It was named and defined by Professor G. D. Harris[2] in 1907 the "Sabine Peninsula" and in 1910 the "Sabine Uplift." It was recognized by him as an uplift of considerable magnitude in the Coastal Plain sediments. Veatch[3] in 1906 recognized a notable deflection in the belts of outcrop of the various formations, but failed to observe the reversal of dip north of the present Caddo field. More recently portions of the uplift have been mapped in detail by Matson and Hopkins,[4] and have been discussed by Dumble.[5]

During the past few years two problems have presented themselves to the writer, the nature and the origin of the uplift, neither of which has been satisfactorily explained. Structurally the area is extremely complicated when examined in detail, but relatively simple when examined as a whole. The attention of the writer has been drawn to the presence of buried hills and ridges near and beneath certain oil fields, and as a result of his experience he is led to suggest

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Sidney Powers, Amerada Petroleum Corporation, Tulsa, Oklahoma.
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[2]G. D. Harris, Rock salt in Louisiana, Geol. Surv. of Louisiana, Bull. 7, 1907, Plate 24; Oil and gas in Louisiana, U. S. Geol. Surv., Bull. 429, 1910.

[3]A. C. Veatch, Geology and underground water resources of northern Louisiana and southern Arkansas, U. S. Geol. Surv., Prof. Paper 46, 1906.

[4]G. C. Matson, The Caddo oil and gas field, Louisiana and Texas, U. S. Geol. Surv., Bull. 619, 1916.

G. C. Matson and O. B. Hopkins, The DeSoto-Red River oil and gas field, Louisiana, U. S. Geol. Surv., Bull. 661c, 1918.

[5]E. T. Dumble, The geology of East Texas, University of Texas. Bull. 1869, 1920, pp. 26-27.

that the Sabine Uplift is a reflection in the Coastal Plain sediments of a positive element of small extent in the earth's crust.

The objects of this paper are to outline briefly this theory of origin, to describe and account for the folding superimposed on the uplift, to call attention to certain divergences and lithologic changes in the stratigraphic section, and to mention the production of petroleum—all without violating the ethics of a petroleum geologist.

In writing on any phase of petroleum geology it is extremely difficult to accredit the origin of many of the views expressed. It is only by free discussion that petroleum geologists can solve the problems which confront them. After a few discussions almost everyone incorporates some of the ideas of others with his own and gives them out as such. It is therefore necessary to state that the writer claims originality for only the one theory mentioned above. Sincere thanks are due to many geologists for ideas here incorporated, and among them may be mentioned J. Y. Snyder, R. T. Hill, F. B. Plummer, W. E. Pratt, Irving Perrine, S. P. Borden, and F. B. Ely. Mr. Pratt has very kindly read the manuscript and has made valuable suggestions.

DESCRIPTION

Judged as a whole the Sabine Uplift is a large, flat-topped dome from which the dip is quaquaversal at a rate of twenty to one hundred fifty feet to the mile, or roughly, one-sixth degree to two degrees. Two conspicuous axes, one northwest-southeast, the other at right angles, lend irregularity to the outline of the dome. The surface of the uplift is undulating with alternating rythmic anticlines and synclines elongated northeast-southwest and compressed in the opposite direction. Several domes of large size, some with steep sides, some with broad tops and gently dipping sides are found on the uplift. Figure 1 shows the outline of the uplift as indicated by the contour on the Nacatoch sand one thousand feet below sea level. The shape of the uplift is essentially as drawn, but the bounding line is purposely made as smooth a curve as possible and it therefore crosses several folds on both the east and west sides. Complete structure contour maps of North Louisiana show the highest elevation, on the top of the Nacatoch, in the Caddo region and in the vicinity of the DeSoto field as approximately five hundred feet below sea level. The highest contour in the Elm Grove gas field, in the center of the

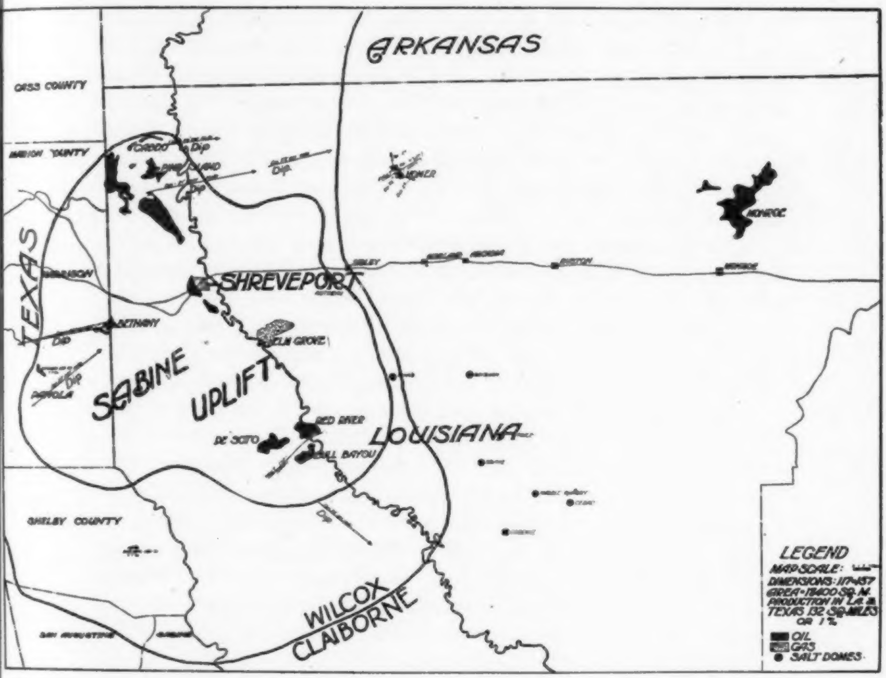

Figure 1. Map of a portion of North Louisiana, Texas and Arkansas, showing the outline of the Sabine Uplift as indicated by a generalized contour on the Nacatoch sand, one thousand feet below sea level. The contact between the Wilcox and Claiborne formations closely approaches the uplift on the east where the Eocene formations are thin, and diverges on the west where they are thick. The oil and gas fields are accurately shown.

uplift, referred to the same datum is six hundred sixty feet; that in the Bethany district on the western edge, seven hundred feet; that in the Bodcaw Lake district on the eastern edge, seven hundred thirty feet; while that at Homer, off the uplift, is seven hundred feet.

No uplift comparable in size to the Sabine Uplift is known in the Coastal Plain. Folds in Alabama are well known, but they are parallel east-west anticlines. The Preston anticline, which crosses Red river between Oklahoma and Texas, is a single, long anticline which apparently reflects a buried area of geanticlinal folding. Moreover, there is no area of folding exposed at the surface nearer to the Sabine Uplift than the Ouachita Mountains in Arkansas, ninty miles north.

Axes of folding in the Ouachita Mountains run approximately east-west; the axis of the Sabine Uplift runs northwest-southeast and the axes of the folds on this uplift run parallel to those of the Ouachitas. Folds between these two areas are unknown and the lack of connection between the two areas is impressive. To explain the Sabine Uplift as due to compression of the coastal sediments as against the Ouachita Mountains is contrary to the field evidence that the uplift is not primarily a series of anticlines, but that it is an enormous north-south terrace. Parallelism to the principle Sabine axis can be seen in the alignment of the salt domes in northern Louisiana, and the connection between the two is very evident, but is not easy to account for. Mr. Matson has called the writer's attention to the parallelism of the Sabine axis to the Mississippi embayment axis. The Balcones fault and the Bend arch in Texas certainly have no connection with the Sabine area.

The Sabine Uplift is believed to be a positive element in the earth's crust which reflects isostatic conditions in the rocks beneath the Coastal Plain sediments. Its configuration is believed to be primarily dependent on factors of equilibrium at depth and secondarily dependent on superimposed folding. This theory may be explained under the comprehensive title, *Positive elements in petroleum geology*.

POSITIVE ELEMENTS IN PETROLEUM GEOLOGY

Positive elements as here defined are segments of the earth's crust which tend to rise, or to remain stable, while adjacent segments tend to sink. Horsts, by this interpretation, are positive; graben,

the reverse. As an example of a positive element the writer has recently called attention to the Llano-Burnet (Central Mineral) region, Texas.[6] Other examples follow.

The importance of buried hills is constantly becoming more evident in oil geology. By liberal interpretation these buried hills may be included with the positive elements when they are reflected at the surface. While the Sabine Uplift is not interpreted as a buried hill, it will be possible by a consideration of buried hills to clarify the description of the larger feature here described.

Healdton claims attention as being the first buried hill described as such in the Midcontinent field. The surface structure is superimposed upon a buried ridge, which evidently stood as an island during a portion of the period of sedimentation in the surrounding sea. Folding produced the anticline in the Permian sediments, but the readjustment and consolidation of the sediments accompanying uplift of the geosynclinal prism of sediments is believed to have had an important effect in developing the fold.

Wells in Kansas have proved the existence of two buried granitic ridges from which occasional monadnocks rose in sharp relief, but not to sufficient height to emerge from the great thickness of Pennsylvanian sediments as yet uneroded. Sharp anticlines reflect the buried topography and these anticlines can be explained by a settling and consolidation of the prism of sediments rather than by tangential thrust from an area of contemporaneous mountain building. Furthermore, the granitic areas seem to have withstood the general depression of the sediments to the west and to have acted as stable elements.

North Texas exhibits similar buried hills at the extensions to Burkburnett as well as at Petrolia and Electra. The buried hills are probably of Ordovician age with granite beneath at Petrolia in the deepest well in North Texas near the Red river. In Montague and Cooke counties to the east highly folded Ordovician rocks and pre-Cambrian granite have been found in deep wells, but it is questionable if surface structure conforms to the buried topography.

Panhandle developments have found acid igneous rock evidently of pre-Cambrian age in Ranch Creek Oil Company, Masterson No. 1, in Potter county. Granite has also been found in a test in New

[6] S. Powers, The Butler salt dome, Freestone county, Texas, Amer. Jour. Sci., Vol. 49, 1920, p. 141.

Mexico west of Amarillo. Evidently buried hills prolong the topography of the Wichita Mountains far westward and extend the province of Appalachian folding into New Mexico.

As a positive element the Llano-Burnet region cannot be traced farther back than Strawn (early middle Pennsylvanian) time in the record of the sediments on the flanks of the massif. It appears to have been merely an island during Strawn time. With the loading of the area south and east in Cretaceous time the massif is believed to have acted as a resisting positive element away from which the coastal sector broke along the Balcones fault line. The region has persisted as a positive element from Strawn time to the present.

The Sabine Uplift may be superimposed over an area of pre-Cambrian rocks which formed a topographic feature on the peneplain at the time of the incursion of the Lower Cretaceous sea. It is believed to be an area which tends to rise like the Llano-Burnet region. It may have risen slightly after Wilcox (Eocene) time, but it certainly did not rise to its present proportions until after the deposition of the Eocene sediments because these are conformable with the Cretaceous sediments. At the beginning of, or probably before the folding, the uplift became accentuated by elevation and in part by settling of the sediments to the greatest degree on the south where the Nacatoch sand is now as high as it is fifty miles to the north. The pre-Cretaceous floor, however, was warped down toward the south during Eagle Ford time, as described below, with consequent thickening of the sediments in that formation southward. Therefore, the pre-Upper Cretaceous and the pre-Cretaceous basements have not become horizontal, but the pre-Eocene basement has become horizontal. This downwarp was a part of the general subsidence of the Coastal Plain area during deposition and was not confined to any limited region.

Homer and Monroe are not portions of the Sabine Uplift, nor are they interpreted as being areas of folding of similar origin. They are related to the second period of folding, or, more accurately expressed, to the period of folding following the period of readjustment and uplift.

FOLDING

Subsequent to and perhaps immediately following the vertical movement which produced the Sabine Uplift compression was exerted either from the geosynclinal prism of sediments on the south or

from the land mass on the north, known as the Ouachita Mountains, or from both. This compression developed the folds which are superimposed on the larger uplift and which have furnished reservoirs for petroleum both on and off the uplift. Still later folding at right angles and parallel to the axis of the original uplift bent the earlier folds at intersections. Accumulation of oil on the north and south sides of the original uplift—the steepest sides—undoubtedly began at the time of that uplift. Many of the anomalies of the present occurrences of oil and gas on the uplift on poorly defined structures, or across both anticlines and synclines, may be explained by the effect of the folding on the original areas of accumulation rather than by local changes in sand conditions. Off the uplift, where the accumulation is related only to the folding, the occurrences of petroleum are in strict accordance with the theory of anticlinal accumulation.

Tangential compression acts with greatest force in depth. Therefore the folds are theoretically more pronounced in the pre-Cambrian rocks, and superposition of structures is possible to a certain extent. Compression exerted on an uplift such as has been postulated would produce the most intense folding at the ends—at the north and south in this instance—with anticlines of considerable magnitude, but not of such intensity between the ends. The Homer-Bethany axis is the longest and most pronounced of these folds. Homer represents a nodal point along the fold sufficiently far from the uplift to feel the full effect of the compression which on the uplift was distributed throughout its length. Thus far no corresponding node has been found in Texas, but this may be because of the greater thickness of sediments in this large geosynclinal area. The Homer anticline broke during folding and separate anticlines developed on both the north and south sides of the fault. The Monroe gas field is probably a large terrace with two super-imposed low anticlines, but it is not on the Bethany-Homer axis of folding.

Without having at hand a complete subsurface map of North Louisiana it is not possible to discuss the great number of parallel folds which cover the Sabine Uplift. Many of them have already been described in detail. The Gusher Bend fault is the only described fault, but other small faults are probably overlooked in the haphazard manner of drilling in proven territory. This fault is normal with a downthrow on the south of approximately two hundred fifty

feet and it represents a reaction following the folding. A very small fault exists north of the Monroe gas field, which was named the Alabama Landing fault by Veatch, but the direction of this fault is reported to be northeast-southwest instead of east-west.

A secondary axis of folding parallel to the axis of the Sabine Uplift has been postulated by some field geologists and two sets of parallel intersecting lines have been drawn to fit this theory. The proof of the theory lies in the drilling now in progress.

An explanation must be added that the outline of the uplift, as shown in Figure 1, based on the contour of the Nacatoch sand one thousand feet below sea level, is so generalized as to magnify the size of the Homer-Bethany axis and to indicate that this narrow fold is even larger and more important than the main uplift. A subsurface structure-contour map will show that several anticlines and synclines were purposely effaced in order to smooth the contour.

GEOLOGIC HISTORY

The age of the Sabine Uplift has never been accurately determined. Harris[7] suggests that the central and western portion may have constituted an island in Claiborne time. Berry[8] maintains on the basis of fossil leaves and not of stratigraphy that the northern portion of Louisiana was a land area during lower and middle Wilcox time. Dumble[9] states that, "the movement at the end of Cretaceous time was sufficient to create the Cretaceous domes and the Sabine Peninsula through local elevation of the Upper Cretaceous sediments 2,500 to 3,000 feet." Matson and Hopkins[10] place the folding as "in part, at least, post-Eocene." Each writer avoids so far as possible the problem of when the uplift and folding took place. This subject can best be presented by reviewing the geologic history.

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[7]Op. cit., p. 121.

[8]E. W. Berry, Erosion intervals in the Eocene of the Mississippi embayment, U. S. Geol. Surv., Prof. Paper 95f, 1915.

[9]Op. cit., p. 261.

[10]U. S. Geol. Surv., Bul. 661c, 1918, p. 119.

Commencing with the Paleozoic land mass, Llanoria,[11] North Louisiana first became an area of deposition at the beginning of Lower Cretaceous time. The thickness of limestones, sandstones, and red shales deposited during this period is known only approximately in Arkansas and is not known in Louisiana because no well has completely penetrated the Trinity sand in Louisiana. R. T. Hill[12] showed that hills were present in the Llano-Burnet region at the beginning of the deposition of the Trinity sand and the same conditions may have prevailed under the Sabine Uplift.

A withdrawal of the sea marked the close of Lower Cretaceous sedimentation, but drilling has not yet shown the structural relationship of the Lower and Upper Cretaceous south of the Arkansas exposures, where the Upper Cretaceous overlaps the older sediments and invades the Mississippian embayment for the first time.

The geologic formation known as the Woodbine sand is below the oil and gas sands which are called by this name. The formation is very similar lithologically to the Trinity sand and the age of the red shales and gumboes found directly beneath the producing oil and gas sands of the Eagle Ford shale may be either Woodbine or Trinity. They are believed to represent the Woodbine formation, because they are usually underlain by fossiliferous limestones correlated with the Lower Cretaceous, but the Woodbine formation and the Lower Cretaceous cannot be separated clearly in well logs. At Monroe the chalk is underlain by a thick series of red gumboes and barren sands, which are believed to be the equivalent of the Eagle Ford and Woodbine formations, but to differ lithologically from the sediments of the same age elsewhere because of their origin from terrigenous sources not far to the north which were not covered by the Lower Cretaceous sea.

Red sediments denote the presence of land conditions not far distant. The red shales of the Woodbine and of the Trinity represent

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[11]E. T. Dumble, Op. cit., pp. 11-13; J. C. Branner, The former extension of the Appalachians across Mississippi, Louisiana, and Texas. Amer. Jour. of Sci., Vol. 4, 1897, p. 357; N. F. Drake, Report on the Colorado coal field of Texas, Fourth Ann. Rept. Geol. Surv. of Texas, 1892; reprint Univ. of Texas Bull. 1775, 1917, p. 16; Charles Schuchert, Bull. Geol. Soc. Amer., Vol. 20, 1910, p. 427; S. Powers, Op. cit., p. 141.

[12]R. T. Hill, Geology and geography of the Black and Grand prairies, Texas, 21st Ann. Rept., U. S. Geol. Surv., 1901, p. 134.

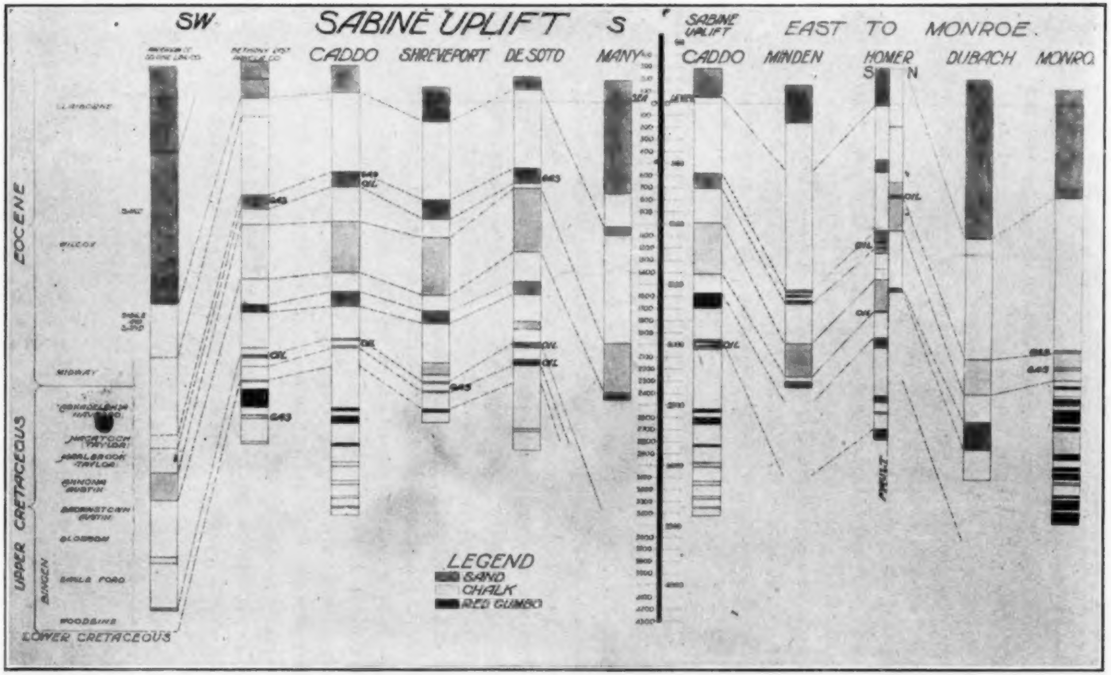

FIGURE 2. Cross-sections of the Sabine Uplift (on the left), and from the uplift east to Monroe (on the right), shown in well logs. Unshaded portions of the logs represent shale and gumbo. Several of them are combinations of a producing well and of a deep dry hole, and by this means the deepest wells in North Louisiana are shown. The section at the left extends from Anderson county, Texas, northeast to Panola county, Texas, and the Caddo field; thence south to Many, which is south of the Uplift. The Shreveport log is a dry hole and therefore the formations are low. The section at the right is practically west-east, and shows the fault at Homer with a slight exaggeration of the down throw on the south.

terrigenous material derived from the deeply weathered Ouachita Mountain region to the north. They appear to represent definite beds deposited under marine conditions and widely distributed. Also, they appear to furnish a horizon marker which can be used in correlation. Red sandstones, which are the near shore phase of such sedimentation, are not present in northwestern Louisiana.

Sands which contain petroleum overlie the red shales. These sands are called Woodbine, but have been shown to be of Eagle Ford age. They are probably lenses in a sandy horizon of broad extent. Two petroleum-bearing sands can be traced through the Red River-DeSoto-Bull Bayou fields. Other sands can be traced in the Caddo field and still other sands in the gas fields. A limestone appears in the section in the vicinity of Shreveport above the oil sands and extends southward. Because of the presence of this limestone, Matson and Hopkins correlate the sands of the Caddo field with shales above the limestone at the southern end of the uplift.

However the sands are correlated, there was a subsidence of between 300 and 400 feet in the southern portion of the present uplift between the deposition of the lowest oil sands and the deposition of the Blossom sand, or else there was a gradual transgression of the sea from the south which caused thicker sedimentation on the south. The former alternative is favored because of the presence of basal sand overlain by a limestone thickening southward and in turn overlain by shales. A transgression of the sea should be marked by the presence of beaches with sands thinning out into shales and probably containing oil in some of the higher lenses. No such lenses have been found in drilling. On the southwest the horizon of the producing sands becomes a limestone, and in East Texas throughout the geosynclinal area sands are unknown in the section except in rare instances.

Stephenson[13] has shown that time and lithologic equivalents in the Upper Cretaceous between central Texas and Louisiana are very different. Lithologic equivalents are given in Figure 2. Time equivalents are as follows:

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[13]L. W. Stephensen, A contribution to the geology of northeastern Texas and southern Oklahoma, U. S. Geol. Surv., Prof. Paper 120h, 1918, pl. 30.

Dallas:	*Shreveport:*	
Navarro formation	Arkadelphia clay Nacatoch sand Marlbrook formation (*in part*)	
Taylor marl	Marlbrook formation (*in part*) Annona chalk Brownstown marl	
Austin chalk	Blossom sand Unnamed clay	Bingen formation
Eagle Ford clay	Eagle Ford clay	
Woodbine sand	Woodbine sand	

Lithologically the Austin and Annona chalks are continuous. The interpretation of the phenomenon has been pointed out to the writer by R. T. Hill. Deep sea or quiet sea conditions favorable for the deposition of chalk first prevailed in central Texas. These conditions migrated eastward with time, giving progressively shallower water westward and deeper water eastward until the time of the deposition of the chalk in Alabama, the youngest chalk according to fossil evidence. There was no Sabine Uplift at this time.

Below the Annona chalk the Blossom sand is persistent horizon. Production from this sand on the uplift is not common, but off the uplift both to the east and west oil is found in the Blossom. The small oil production at Elm Grove, near the center of the uplift is principally from this sand.

Above the Annona chalk the Nacatoch sand forms the best marked and most persistent sand horizon on the uplift. This sand is calcareous and eastward it becomes largely limestone. At Monroe (Figure 2), the Nacatoch may rest directly on the Annona chalk. In the DeSoto-Red River area the Brownstown marl becomes a chalk and this condition gives rise to a greater thickness of chalk than elsewhere, the top of the chalk commencing almost directly below the Nacatoch. Where the Nacatoch does not contain petroleum it is usually not logged. The continuation of the sandy horizon far into the Texas geosynclinal is questionable.

The close of the Upper Cretaceous was marked by another withdrawal of the sea which is greatly emphazised by stratigraphic, but not by structural geologists. Dumble places the uplift of the Sabine region at this time, but his admission of the presence of Midway on the uplift of the same thickness as off the uplift and conformable

with the Nacatoch sand of Upper Cretaceous age is proof that his conclusion is incorrect. Certain salt domes commenced to grow during Cretaceous time and attained considerable relative height at the close of the Cretaceous, but no unconformities similar to those around salt domes have been found around the Sabine area.

Midway shales, of basal Eocene age, are recognized throughout the Gulf Coast region. The Wilcox formation likewise has been traced continuously over a great area. But, as stated above, Berry questions the age of the Wilcox beds which appear on the uplift. The Midway is a marine formation. The northern portion of the Wilcox was deposited under littoral or palustrine conditions and lignite is very abundant. Certain lignite beds can be traced in well logs and their dip conforms to that of the Nacatoch sand. It has been shown what the Wilcox thickens greatly to the southwest[14] and Figures 1 and 2 portray this thickening in the close parallelism of the thousand-foot contour on the Nacatoch with the Wilcox-Claiborne contact on the east and the very marked divergence from this contact on the west.

Dumble[15] summarizes the evidence of the age of Wilcox in east Texas. He states the conclusions of Harris that the highest Wilcox beds of North Louisiana at Sabinetown are marine and belong to the upper Wilcox (Woods Bluff), while the beds at a lower horizon five miles north of Pendleton belong to the lower Wilcox (Nanafalia). Veatch and Dumble admit the beds thirteen miles north to be older than those classed by Harris as lower Wilcox, yet Berry finds that the plants indicate middle Wilcox. Still farther north, and lower stratigraphically, Berry concludes that the beds in Harrison county at Port Caddo Landing are of late Wilcox age.

In view of the fact that the Wilcox beds on the top of the Sabine Uplift are conformable to the Nacatoch sand, and to the fact that they dip beneath beds classed as lower Wilcox on the evidence of marine fossils the writer believes that they are of lower Wilcox age instead of upper Wilcox, as Berry would have them. In any case there is no evidence of an uplift in northwestern Louisiana until after Wilcox time.

Claiborne sediments are structurally conformable with those

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[14]S. Powers, Op. cit., p. 137.

[15]Op. cit., pp. 37-55.

previously deposited except around salt domes. At Homer the conformity of the Mount Selman (St. Maurice), and of the Wilcox are excellently shown as the Wilcox in outcrop is confined to the highest part of the northern anticline. Claiborne beds are not found on the Sabine Uplift with one or two doubtful exceptions. The amount of uplift indicates that they would have been removed by erosion if ever deposited. It is very possible that the first differential movement of the uplift took place at this time and that this uplift first became defined before Claiborne deposition.

Sedimentation continued without structural disturbance east, west, and south of the Sabine region until after Oligocene time. Anticlines of the same generation of folding as the folds of the Sabine Uplift are being sought in the Catahoula (Corrigan) sandstone. During later Eocene and during Oligocene time the uplift on the north may have become accentuated.

The final definition of the original uplift and of the folding is believed to date from the post-Oligocene erosion interval, probably subsequent to deposition of the Fleming clays. In Texas the Oakville, the base of the next higher formation above these clays, is marked by a "conglomerate of rolled Cretaceous fossils, oysters, gryphaea and other bivalves, sometimes unbroken but often ground almost to sand."[16] Dumble further states that "at the close of the Tertiary there was a repetition, perhaps on a somewhat grander scale of the movements which accompanied the close of the Cretaceous."[17]

Folding initiated a period of erosion followed by peneplanation. Gravels from the Ouachita and Arbuckle mountains were spread over the surface of the peneplain at the beginning of the present erosion cycle and these gravels have their marine phase in the Lafayette, Reynosa and Lissie gravels of the Coast. Remnants of the peneplain gravels may be traced from the gravel terraces of Arkansas along the higher hills of the intervening region to the gravel beds of the Coast.

Red river is probably a very old drainage system which made its way across the Coastal Plain as new formations were successively elevated. If the present interpretation of geologic history is correct

[16]E. T. Dumble, Op. cit., p. 238.
[17]Idem, p. 261.

this river commenced to cross the outcrop of the Wilcox formation soon after its deposition and has maintained its course through all the cycles of uplift and of folding.

PRODUCTION OF PETROLEUM

HISTORY OF DEVELOPMENT

The first successful oil wells in North Louisiana were drilled in 1904, and as a result of the discovery of oil the Caddo field was developed. Maximum production at Caddo was in 1913. Wildcat drilling led to the discovery of gas at Shreveport, Cedar Grove, and Elm Grove in 1912, near the center of the uplift. Gas was discovered near Naborton, DeSoto parish, in 1912, and oil was found in the same region in 1913. The DeSoto field was rapidly developed and attained maximum production in 1914. Oil was found in Red River parish in 1914, and the famous Gusher Bend in the Red river was exploited in 1915. A small field was developed at Pelican in DeSoto and Sabine parishes in 1913. The first production of petroleum off the uplift was north of Monroe in Morehouse and Ouachita parishes, where gas was discovered in 1917.

At a time when interest in North Louisiana was waning the Pine Island field was brought in during the Spring of 1918, as an extension to the Caddo district, with light oil in the Annona chalk and heavy oil in the Woodbine sand. Production declined with remarkable rapidity, but this extension stimulated the deepening of wells on the edges of production, and as a result of deepening old wells a deeper producing oil sand was found on the Wemple lease of the Texas Company, south of the Gusher Bend fault, in September, 1918. This led to the development of Bull Bayou field in 1919.

In January, 1919, the Consolidated & Progressive Oil Company of New York, discovered oil at Homer, and in August the Standard Oil Company brought in the first deep oil well. Development was rapid and the field was soon quite well defined as covering approximately two sections. Salt water appeared in the deeper sand along the edge wells and it is gradually enroaching on other wells.

STRUCTURES

Caddo needs no description here because of the adequate treatment by Matson. The Pine Island development was along a con-

tinuation of one of the anticlines mapped by him. Still other pools may be opened by a careful examination of structural conditions and by careful drilling. Gas and heavy oil was produced from the Nacatoch sand, oil from the Woodbine and some oil at Oil City and Pine Island from the Annona chalk.

The Shreveport, Cedar Grove, and Elm Grove gas fields are on normal anticlines. Production of gas in the first two is principally from the Woodbine, in the last principally from the Nacatoch with some oil in the chalk, in the Blossom, and in the Woodbine. Gas is also produced from the Woodbine.

The DeSoto-Red River fields have been carefully mapped and adequately described by Matson and Hopkins. Gas comes from the Nacatoch and oil from the Woodbine.

The Bull Bayou field has been developed along a minor plunging fold south of the Gusher Bend fault, which is mapped by Matson and Hopkins. There is evidence of a larger barren fold of the same nature farther south. Pelican wells are also described by Matson and Hopkins. Their map shows that the largest structures in the region are unproductive.

Bethany production is on an anticline along the Bethany-Homer axis of folding. Gas is found in the Nacatoch, oil in the Woodbine horizon, which is principally limestone, and gas in limestone of Lower Cretaceous age, Nowhere else in Louisiana is the Lower Cretaceous thoroughly tested. Oil is found in the Blossom sand in the Waterman Lumber Company field in Panola county, and in the Pickering Lumber Company field in Shelby county. Oil is also produced from the Nacatoch in the latter field. The subsurface of these fields is inadequately known, but both were located by surface anticlines in Wilcox shales.

Many anticlines and domes on the top and sides of the uplift are dry although their existence has been proved by drilling. The explanation is probably found in the accumulation of petroleum during the period of uplift prior to the folding which produced these structures. In spite of the presence of these barren structures the areas most promising for future production in North Louisian are on the sides of the uplift. New production is to be expected at both the north and south ends of the uplift, but especially at the north end, for there the accumulation is far more extensive.

Off the uplift oil is produced on the two anticlines at Homer; in the Nacatoch sand on the northern, in the Nacatoch sand and in the Blossom sand on the southern anticline. The fault which separates these structures runs north sixty degrees east and has a downward displacement of 250 feet or more on the south side. The hade of the fault is unknown. The fault may be observed in the field along a fault-line valley running into a topographic dome beneath which the structural domes are located. Small faults subsidiary to the large one may be observed along the northern sloping hill on the Haynesville road, Sec. 15, T. 21 N., R. 7 W. The fault may branch in the Homer field in Sec. 19, and run westward in a curve through Sec. 24, T. 21 N., R. 8 W. Both anticlines are elongated parallel to the major fault. The elevation of the Nacatoch sand below sea level on the top of the northern anticline is 700 feet; on the southern anticline, 1,000 feet. The dips off the anticline range from two degrees to six degrees. Up to March, 1920, no wells in proven territory on the northern anticline have been drilled deeper than the Nacatoch, and on the southern anticline no well has gone deeper than the Blossom. Since this date a deep test north of the fault found no Blossom or Woodbine production.

Well logs show limestone above and below the producing Nacatoch sand. Deep tests record the Annona chalk as chalk and shale or simply as shale. Logs north of the fault show very little interval between Nacatoch limestone and Annona chalk, while logs south of the fault show a considerable interval (Figure 2). These lithologic changes are believed to be regional in character.

The Monroe gas field is the present eastern limit of production in the Cretaceous sediments. Well logs record two or more gas sands, one directly above chalk, one in the middle of the chalk if all the chalk is logged. Directly beneath the chalk, red gumbo is encountered. The deepest wells record only gumbo, shale, and sand below the chalk. No fossils have been secured from these wells. The age of the formations is questionable. In the absence of fossils the upper gas sands may be interpreted as Nacatoch resting directly on the Annona chalk. The red gumbo may be referred to the Eagle Ford as stated above and the color may be explained by proximity to shore. On the eastern side of the Mississippi embayment, however, the lithology of the Cretaceous appears to be the same as in northwestern Louisiana.

Two anticlines are known at Monroe and they probably form part of a nose extending southeastward. The regional strike is northeast-southwest.

COMPARISONS

Total production statistics in barrels to January 1, 1920, for North Louisiana, are as follows:

	Barrels
Caddo	81,377,968
DeSoto-Red River-Bull Bayou	28,618,736
Homer (To January 20, 1920)	2,600,270
Total North Louisiana	112,596,974

Daily production on March 10, 1920, was as follows:

Caddo	17,864
Bull Bayou	17,212
Homer	78,122
Total	113,198

Total production of Eastland-Stephens counties and Desdemona, Texas, to March, 1920, was approximately as follows:

Stephens county	12,500,000
Eastland county	25,500,000
Desdemona	7,500,000
Total	44,500,000

Total production in Oklahoma to January 1, 1920, was 987, 596,009 barrels, with production for 1919, of 89,959,552 barrels.

To go farther afield, one well in Mexico produced as much oil in its life as all the North Louisiana fields to date.

Production in Caddo has been very steady with slow decline. Pine Island was an exception. Production in DeSoto-Red River-Bull Bayou has been flush with rapid decline to nothing after three to four years. However, production from the Nacatoch sand has been satisfactory and will have a moderately slow decline. In the Blossom sand the gushers produced a percentage of salt water and emulsion from the beginning. Salt water has appeared in the edge wells and is progressing toward the center of the very limited area

of production. An extremely rapid decline is expected in the deep sand. Statistics for the older fields supplementary to those in the Survey Bulletins have been published with decline curves by Beal.[18] Total per acre production in the North Louisiana fields has not been closely studied. Beal gives figures for three of the more productive leases in the Caddo field as 12,200, 22,000 and 44,800 barrels, respectively. An estimate of the average yield at Caddo is 12,000 to 14,000 barrels, for DeSoto-Red River-Bull Bayou, 8,000 barrels.

Gravity of oil in Louisiana has been discussed by Matson and Hopkins[19] in connection with analyses of oil. For commercial purposes the Baume gravity is not generally taken when the oil is fresh, hence the gravity is lower. A table given below shows the range of gravity of oil produced from different sands and emphasizes the uniformity of the Woodbine oil in all fields except Pine Island. The Nacatoch oil is heavy at Caddo (Hosston), light at Pelican, but it is practically the same as the Woodbine elsewhere. The Annona chalk oil at Pine Island is heavier than normal Woodbine oil, and the Blossom sand oil at Elm Grove is approximately the same gravity. Oil in the Woodbine sand in the DeSoto, Red River, and Bull Bayou fields is of uniform gravity. The derivation of the Blossom and Woodbine oil is from the Eagle Ford shale; that of the Nacatoch oil and gas from the Arkadelphia clay and Marlbrook formation.

Caddo oil contains a high percentage of gasoline, DeSoto-Red River-Bull-Bayou oil contains a high percentage of kerosene; hence Caddo oil brings a higher price, although the gravity is approximately the same. Panola county oil resembles Caddo oil in gasoline content; Shelby county oil resembles DeSoto oil in kerosene content. Homer oil in both sands is the same gravity. This has been explained as due to migration of the oil along the fault from a common source, but other explanations may be offered because the same condition exists in Shelby county where there is no fault. Commercial figures for gravity in Baume degrees follow:

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[18]C. H. Beal. The decline and ultimate production of oil wells, with notes on the valuation of oil properties. Bureau of Mines, Bull. 177, 1919, pp. 154-161; Ralph Arnold et al, Manual for the oil and gas industry, Treasury Department, 1919, pp. 140-7; Ralph Arnold, J. L. Dowell and others, Manual for oil and gas industry, Wiley & Sons, 1920, pp. 137-8.

[19]Op. cit., pp. 128-130.

Field	*Sand*	*Depth Feet*	*Range of Gravity*	*Average Gravity*
Caddo	Woodbine	2200-2350	32-43	38, 42
	Nacatoch	1050	18-22	20
Pine Island	Woodbine	2250-2300	19-28	25-26
	Annona Chalk	1400		32-34
DeSoto	Woodbine	2450	38-42	41
Red River	Woodbine	2465	38-42	41
Bull Bayou	Woodbine	2725	40-42	40-42
Pelican	Woodbine	2970-3200		41-42
	Nacatoch	1500		47
Elm Grove	Blossom	1545		32
Bethany	Woodbine	2450		36-40
Waterman Lbr. Co., Panola Co.	Blossom	2025		40
Pickering Lbr. Co., Shelby Co.	Blossom	2900		40
	Nacatoch	1940		40
Homer	Blossom	2100		38-40
	Nacatoch	1100-1500		38-40

In conclusion it may be stated that North Louisiana can never rival Oklahoma or North Texas in oil production. Oklahoma has in single years produced more oil than North Louisiana from beginning to date. New fields will undoubtedly be opened in North Louisiana for years to come where least expected at present. The geologist, however, works at a distinct disadvantage in locating new fields, because of the scarcity of outcrops and because of the abundance of crossbedding in all the Eocene formations. At least five producing anticlines have been located from surface exposures by geologists and drilling has been initiated on geological recommendation. Subsurface investigations have led to the discovery of other anticlines. Therefore the geologist has proved his value both in surface and in subsurface investigations, and while he cannot assure the presence of petroleum in structurally favorable areas, he can at least condemn as impossible much of the area now being tested.

THE PETROLEUM PRODUCTION ENGINEER AND HIS RELATION TO FUTURE PRODUCTION

A. W. AMBROSE

INTRODUCTION

It is of gravest importance to the American public that this country be afforded an adequate future supply of petroleum. It is vitally necessary to our industrial progress. European nations have realized the importance of a supply of petroleum and are encouraging their nationals to develop foreign fields.

It is recognized that the recovery of oil from sands is very low; perhaps only 20 per cent of that underground is brought to the surface. It is also recognized by experts who have studied the problem closely, that the oil now in the sands underground will not adequately meet future needs. With these startling facts before us, the importance of any man who can increase the recoverable oil is readily apparent. Such is the function of a petroleum production engineer.

The writer will review briefly the future demand and supply of crude petroleum, also the possibilities of substitutes, for the purpose of emphasizing how we must in the immediate future depend on a supply from our oil fields.

RELATION OF THE UNITED STATES TO THE WORLD OUTPUT

The United States has produced about 60 per cent of the world's total output, and we are today maintaining that same commanding lead. This lead in production should be viewed with alarm rather than pride, because we have been rapidly depleting our supply while petroleum resources of foreign fields have lain dormant.

In furnishing this valuable resource of the world's consumption we have withdrawn approximately 4.5 billion barrels of oil, and

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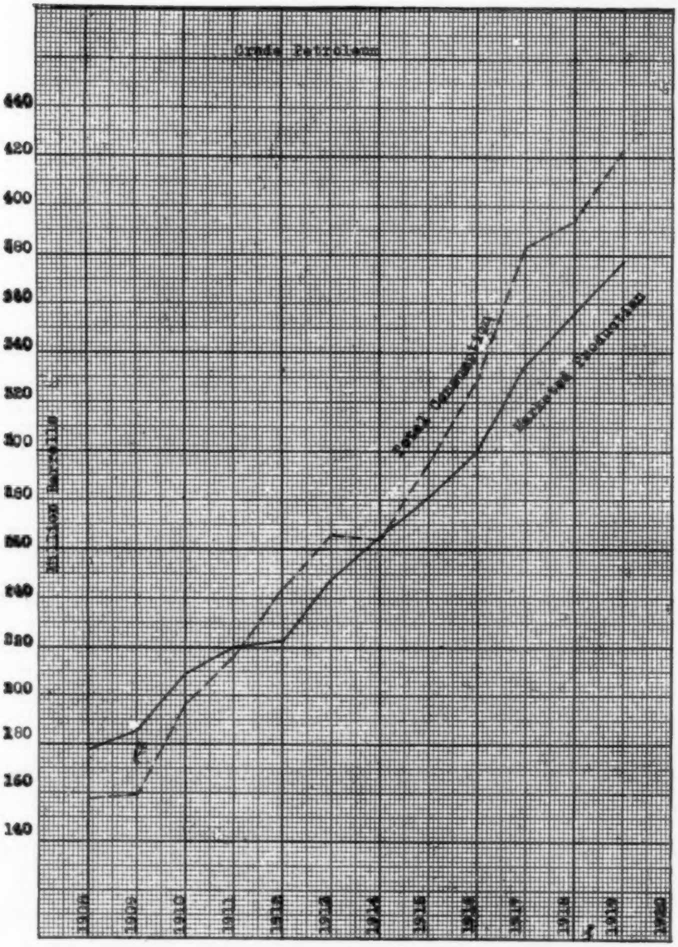

FIGURE 1. Curve showing relation between total consumption and marketed production of crude oil in the United States (after U. S. Geological Survey).

according to figures of the United States Geological Survey this comprises about 40 per cent of the available supply underground. We have therefore only 60 per cent available for the future. If it were possible to produce all of this oil at the same rate as during 1919, our supply would last only twenty years. This, of course, will not be the case, and we may expect to find producing wells in this country at least fifty years from today.

FUTURE DEMANDS OF CRUDE PETROLEUM

Consumption of crude petroelum has increased steadily in the last few years. This is clearly shown by Figure 1. It is true

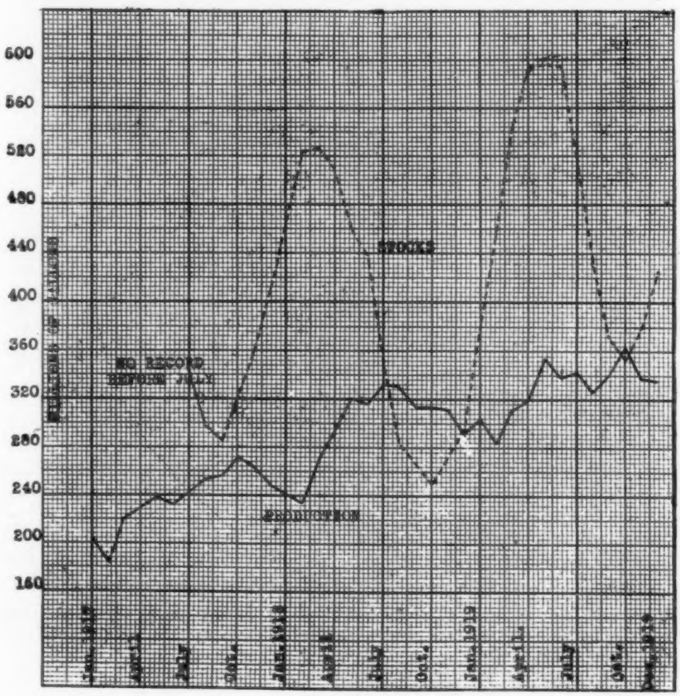

FIGURE 2. Curve showing gasoline stocks and production.

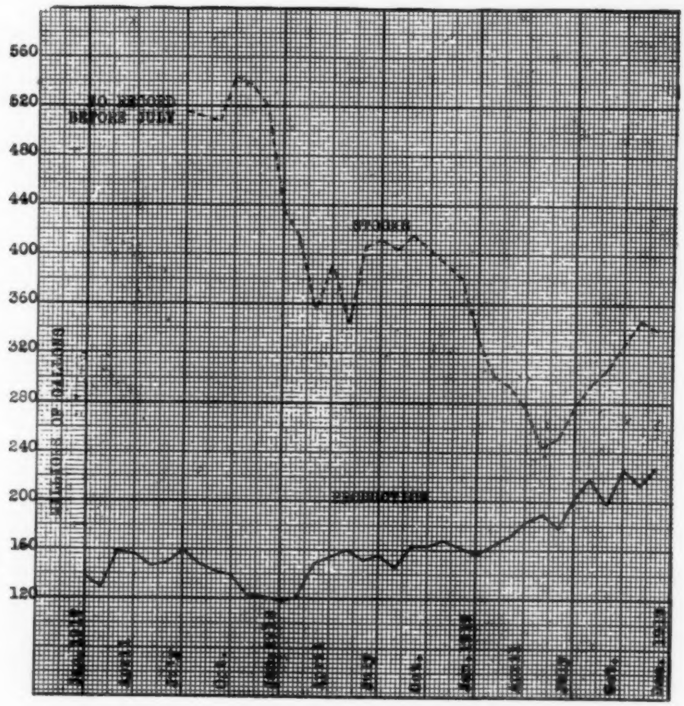

FIGURE 3. Curve showing kerosene stocks and production.

the consumption during 1919 was about equal to that of 1918. This was to be expected, however, for upon the cessation of hostilities, there was a sudden decrease in the consumption of fuel oil by patrolling destroyers and battleships and less demand of gasoline by airplanes and trucks. In addition, domestic industries are slow in changing from a war to a peace footing. A study of statistics relating to petroleum products indicates an increased consumption of crude oil.

PETROLEUM PRODUCTS

The four principal products of petroleum are: Gasoline, kerosene, fuel oil, and lubricating oil.

Gasoline—Gasoline runs our automobiles, trucks, farm tractors, motor boats, aeroplanes, and is in fact, the basis for the future development of the internal combustion motor. As an example, our automobile manufacturers are making rapid progress in increasing the automobile output, in spite of the high prices of labor and raw material. On January 1st of this year there were about 7,500,000 cars and trucks, an increase of 1,500,000 during the year 1919. There will probably be about 9,500,000 by the end of this year. With improved roads the farmer is coming to look more and more

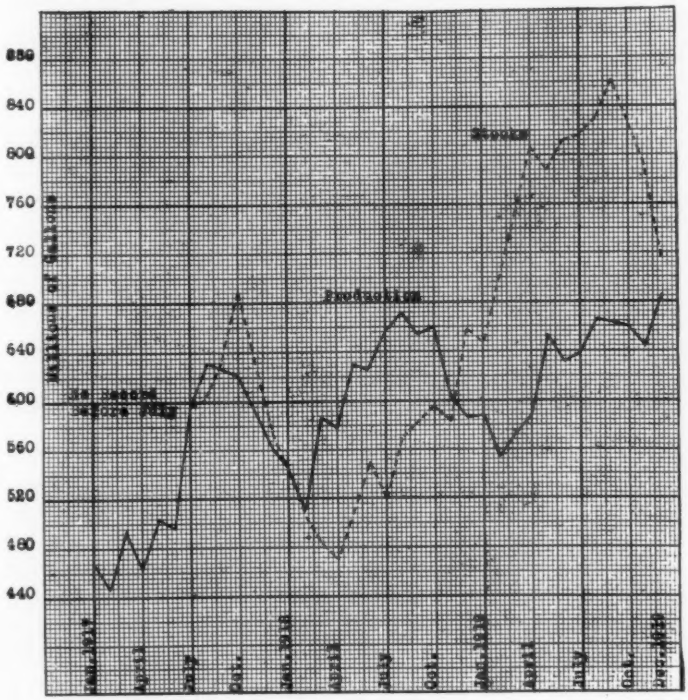

FIGURE 4. Curve showing fuel and gas oil stocks and production.

to the combustion motor as his source of power in hauling material to market and in tilling the land. The demand for gasoline will increase with industrial progress. (See Figure 2 for gasoline stocks and productions.)

Kerosene—Kerosene is a commercial key to the market of China and South American countries, and as shown by Figure 3 our stocks are all too low.

Fuel Oil—Fuel Oil is the strategic base for our battle fleet and our contemplated merchant marine. The recent war has shown it to be a military essential. The Diesel engine will soon be a dominant factor in marine engines. Within a few years the merchant marine will need 50,000,000 to 100,000,000 barrels of fuel oil in addition to that now consumed. (See Figure 4 for fuel oil stocks and production.)

Lubricating Oil—Lubricating oil is absolutely essential to industrial life and without it our machinery could not turn. The amount of lubricating oil made, however, is dependent upon the industrial demand.

DEMAND OF PETROLEUM PRODUCTS

The salient features just mentioned are: (1) There will be an increased demand for gasoline; (2) Kerosene stocks are low; (3) There will be an increased demand for fuel oil.

In other words, the consumption of petroleum products, hence crude oil, will be much greater than at present, if the supply is available.

FUTURE SUPPLY OF PETROLEUM

Let us consider the future sources of supply. It is true there may be future periods of temporary flush production, but these should not be considered in viewing the future supply of petroleum from the standpoint of our national welfare. These temporary peaks will not materially affect the production over a long period of time. Experts who have made a close study of the situation predict that within the next two to five years the production of crude oil from American oil fields will start to decline and from that time on we will have a smaller yield each year. As previously stated, 40 per cent of the oil from American oil fields has been produced. The

possibilities of new fields is brought out by Gilbert and Pogue,[1] "Between 1908 and 1916, during which time the most active exploration campaign in the history of oil development was carried on, the reserve was enlarged by only 1,200,000,000 barrels, a scant three years' supply at the present rate of consumption." The rapid decline of the wells in the new fields of Texas has brought clearly to mind that the supply in these fields is not as big as they first promised. Even though these estimates are 100 per cent too low, still the situation is far from satisfactory.

In conclusion it is safe to say that according to our best knowledge, the future supply of petroleum will not be equal to the future demands. What sources are available then for avoiding a serious shortage, which would almost mean a national calamity?

This problem can perhaps be met in two ways: (1) A better utilization of the crude oil now available; (2) Obtaining greater supplies of crude oil.

It is not the purpose of this paper to enter into a discussion of the better utilization of crude oil. These may be briefly mentioned, however, as follows: (1) Active development and use of Diesel type engines for use of the heavier fuel oils; (2) Development of gasoline substitutes; (3) Cracking of fuel oils into gasoline.

Under the heading of obtaining greater supplies of crude oil comes: (1) Increase the imports from foreign oil fields; (2) Development of foreign oil fields by American capital; (3) The oil shale industry should be established on a commerical basis as soon as is practicable; (4) Petroleum engineers should endeavor to increase the recovery from our oil fields.

The different subjects just mentioned may be reviewed very briefly in order to point out how that, after all, we must look largely to our own oil fields.

Diesel Engine—The development of the Diesel engine presents one of the most practical means for obtaining a maximum use of our petroleum products. Figure 5 shows that during 1918 about 58 per cent of our total oils were turned out as fuel oils, which means that 58 per cent of our petroleum products were not used to the best

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[1]Gilbert, Chester G., and Pogue, Joseph E., "The Energy Resources of the United States. A Field for Reconstruction." Smithsonian Institution Bulletin 102, Vol. 1. p. 68.

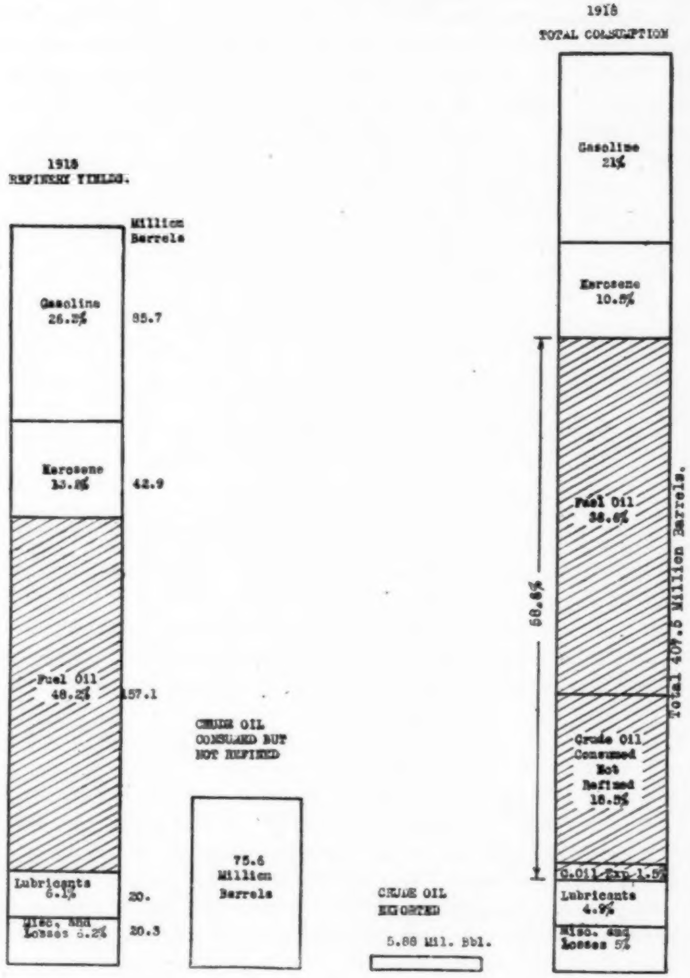


FIGURE 5. Chart showing utilization of crude petroleum in 1918.

advantage. The answer seems to be for the mechanical engineer and the engine designer to cooperate for developing the Diesel engine, which has an over all thermal efficiency 2.3 times greater than the maximum over all thermal efficiencies found with condensing steam engines using superheated steam, and from 3.6 to 5.6 times greater than the efficiency of non-condensing steam engines. It is very evident, therefore, that it is a criminal waste to burn fuel under boilers if the same power can be developed by Diesel type engines.

Gasoline Substitutes—Light oils produced from coal in by-product coke ovens during 1919 is estimated at 90,000,000 gallons, or about 2.3 per cent of the total amount of gasoline produced in 1918.

Grain alcohol has large potential possibilities, although during 1918 it was estimated that this was only about 2 per cent of the gasoline production. The future of alcohol is dependent upon proper return of money for agricultural development. It is not probable, however, that the production of light oils from by-product coke ovens, or grain alcohol, will be on the market to compete with the present price of gasoline.

Cracking of Fuel Oils into Gasoline—Cracking of heavier oils is of commercial possibility, but when fuel oil is in large demand for cracking purposes the price will rise. It then develops into an economic balance between the price of fuel oil plus cracking costs and the price of gasoline.

Imports from Foreign Fields—It is true that it would be possible to import considerable oil from foreign fields, but whenever we are dependent upon foreign sources of supply we lose our economic independence; also transporting oil from foreign fields takes tankers, which are expensive. It is far better to have an available supply in this country in case of military need. We have, heretofore, generally considered Mexico as having an unlimited supply, but the appearance of water in some of the larger wells has awakened us to the realization that even this supply is limited.

Development of Foreign Oil Fields—American capital should be encouraged to make an earnest endeavor to develop foreign oil fields. This matter, however, is not one for consideration in this paper.

Oil Shale—Oil shale will undoubtedly materially assist in maintaining our present dominant position in the future. The practice

of distilling from shale has been in operation in Scotland for many years, but the output of Scotch plants is negligible in comparison with our output. In 1916 the total production of the Scotch shale industry, of which we hear so much, was less than three days' production of oil in this country. Futhermore, oil shale requires a large initial investment and with such a heavy initial expenditure, development of oil shale will be slow. It will be several years before this industry is on a commercial basis.

From the above discussion, we may conclude that there will be an ever increasing demand for petroleum products, and that to meet this demand it is necessary to rely to a large extent upon our own oil fields. The production from our known fields will soon start to decline, however. It is important, therefore, that we obtain a maximum output from them. The petroleum production engineer is of vital assistance in this work.

THE PETROLEUM PRODUCTION ENGINEER

Perhaps under present operating conditions it is safe to say we do not recover more than 20 per cent of the original oil undergound, and it is the function of the petroleum production engineer to work out methods and means for increasing this figure. Oil companies have in the past employed hundreds of men to locate new pools, while we have devoted very little attention to a scientific study of methods for increasing recovery of oil from our known pools. Perhaps ninety-nine technically trained men have devoted their attention to locating new pools where one man has scientifically studied production methods. If 75 to 80 per cent of the oil is left underground, why would it not be good business practice for the companies to devote attention to recovering that supply now going to waste.

It has been definitely established that water has ruined completely many fields, but on the other hand many instances can be cited where water problems have been corrected even after the field has been considered hopelessly lost. We find large mining companies employing engineers to develop and direct their companies. There is certainly need for men of proper training and experience to handle oil companies. We find our geologists have devoted the bulk of their attention to straight areal geologic problems rather than to production problems. It is safe to say that if 10 per cent of the men

employed in locating new pools were studying production problems, we would find a remarkable increase in our recovery percentage.

A petroleum production engineer cannot become such over night. He should be a mining, civil or mechanical engineer, who has studied both geology and chemistry. Such a man should go into the oil field on the completion of his college course with a view of starting in on the well pulling gang, or the pipe line gang, and work up through various positions, such as pumper, roustabout, etc., to a tool dresser and driller. He then obtains a familiarity with drilling and operating conditions. Another method for obtaining proper experience is for the engineer to be located in the oil fields closely associated with the drillers and drilling and operating conditions. There he compiles logs, geologic cross-sections, underground structure-contour maps, peg models, and other data which will assist him in making a detailed study of the conditions underground. This man should make an effort to establish friendly relations with the non-technical field men, and thereby engender a spirit of good feeling rather than one of antagonism. Too often do we find the driller and geologist with no respect for each other. This, of course, is not healthy for the best accomplishments and the success of the company. He should visit drilling wells daily and work closely with the drillers in the collection of formation samples and other data.

The aim of the petroleum production engineer should be to study every condition in the field in regard to the operation of wells which will protect the oil sands against waste, prevent any losses of oil or gas underground, due to water or other cause. To best bring this about certain problems which he may handle, are listed. These may be enumerated as follows: (1) keeping of records; (2) preparation of data; (3) correlation of surface and underground geology; (4) water problems; (5) casing depths; (6) underground losses; (7) oil sands, location of productive sands, their thickness and quality of oil; (8) well depths; (9) new well locations and extension of the field; (10) future well production; (11) gauging of oil wells; (12) perforations and setting screen pipe; (13) fluid levels and tubing depths; (14) shooting of oil wells; and (15) methods for extracting more oil from the oil bearing formations.

The duties of a petroleum production engineer have been discussed in the issue of February 1, 1920, of the Mineral Records, published

by the United States Bureau of Mines. These will not be elaborated in this paper.

In properties which have been producing for a considerable period of time he should study methods for increasing recovery of oil from sands. Perhaps this can be accomplished by the use of compressed air, by the use of regulated gas pressures, by cleaning out the wells, or by underreaming the hole to a large diameter. Possibly acids or electric or steam heating will increase production. Again, lowering the pump depth, a change of pumps, a change in the rate of pumping, or shooting or swabbing will increase the production in certain wells. In all such work production curves should be used to show whether the loss in production, due to closing down the well while being worked on, is more than offset by the increased production. Constant attention should be given to the actual dollars and cents side of such tests, for while certain experiments may be of interest, the engineer should consider that the management is primarily interested in financial returns, and in every accomplishment of such work the financial value of the work should be determined. To do this properly, the preparation of good records and collection of data for these records should be installed immediately.

He should always bear in mind, however, that the operator's greatest enemy is water, and he should notice with alarm any wells which denote a sudden increase in water. The source of this water should be determined as quickly as possible, followed immediately by corrective measures on the well or wells at fault.

Numerous instances can be cited where the work of the petroleum production engineer has been of material advantage. Two instances may be cited. In some work done by the Bureau of Mines in Wyoming a well was making only water. After a detailed underground study, repair work was done on this well, which resulted in the well coming back with a production of 600 barrels of oil per day. Another example is in the case of some work done by the Bureau of Mines at Cushing, Oklahoma, where, in cooperation with the oil companies, the daily production of various wells worked upon increased the production about 4,700 barrels of oil per day. In one particular case repairing a well resulted in not only shutting off the water in the well at fault, but a well 1,300 feet away, which was making about 25 barrels of oil and much water, came back flowing over 600 barrels

of oil per day. The repair was preceded by detailed underground study, including cross-sections, etc.

It is impossible to conceive the enormous waste caused by water in many fields, but the operator should consider the invasion of water as seriously as he would consider a fire destroying the tanks of oil at the surface. It is the petroleum production engineer who, with a scientific and practical training, can be of inestimable service in avoiding these losses.

INTER-RELATIONS OF THE FOLDS OF OSAGE COUNTY, OKLAHOMA

C.V. Millikan

The United States Geological Survey has published in Bulletins 641-B, 691-C and 686 A-V structure maps of a large part of Osage county. In Bulletins 641-B and 691-C (Foraker Quadrangle) the strata are mapped with contour interval of five feet, which will show a larger number of folds by closed contours than that area covered by Bulletin 686, in which the contour interval is ten feet.

The large compact area and detailed mapping afford an excellent opportunity for the study of the inter-relations of the folds, and it is the purpose of this paper to point out some of these relations.

In respect to the attitude of the strata the Osage Nation is divisible into Western Osage and Eastern Osage. The division extends from the northwest corner of T. 22 N., R. 7 E. to the northwest corner of T 27 N., R. 9 E., and thence N. 45 degrees to the state line (Figure 1).

The Western Osage is a relatively evenly westward dipping monocline, with comparatively little folding. Because of the difference of contour interval mentioned above, the number of folds shown in the northern part is unduly large compared with the rest of the area. The strike in Range 7 is about N. 5° E. To the west the strike becomes north. The average dip is about 38.7 feet to the mile.

In the Eastern Osage folds are quite numerous and faulting is frequent. The general strike or dip in any locality is hard to determine because of the numerous folds. The general strike is about N. 10° E., except in the southwestern corner where it changes to about N. 35° E. The average dip is about 36.6 feet to the mile.

The up folds are mostly slightly elongated or irregular domes, which vary in enclosed area from a few acres up to about seven square miles. The average is a little less than one square mile. Basins are almost as numerous as the domes, but the average size is a little smaller.

C. V. Millikan, Stillwater, Okla.

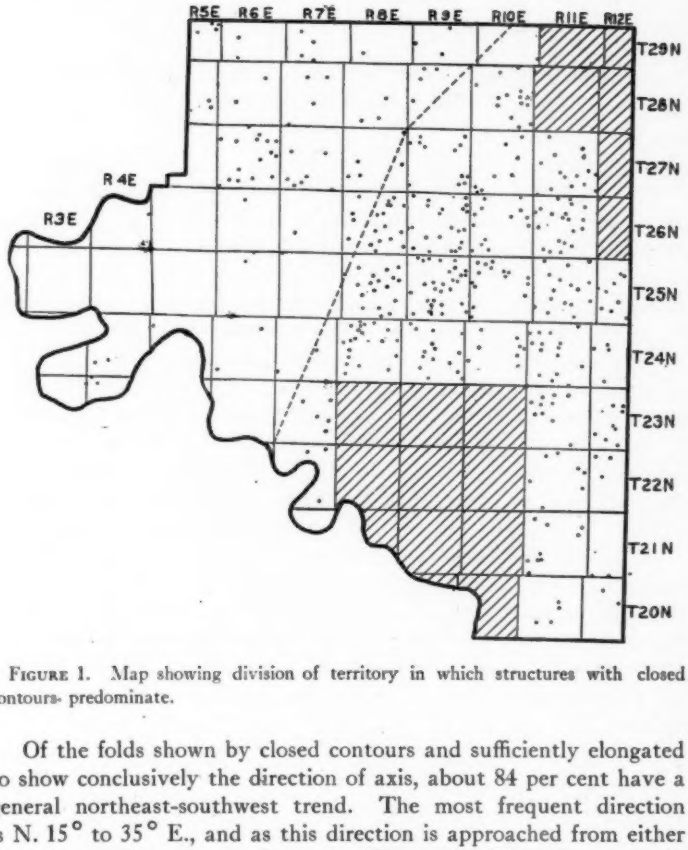


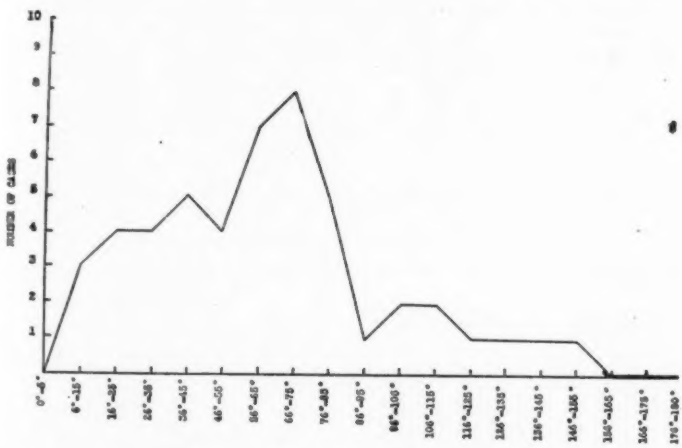
FIGURE 1. Map showing division of territory in which structures with closed contours predominate.

Of the folds shown by closed contours and sufficiently elongated to show conclusively the direction of axis, about 84 per cent have a general northeast-southwest trend. The most frequent direction is N. 15° to 35° E., and as this direction is approached from either side the number of cases increases (Figure 2). There is no area in which any one direction is predominant.

The larger oil pools, those having not less than fifteen wells and lying wholly within the mapped area, also have a general northeast-southwest trend, which is roughly parallel to the general trend of the folds. The most frequent direction is N. 15° to 30° E. So far as they have been developed, the pools to the north have a much more east-west trend than those to the south. The geographic

distribution of the pools does not tend toward any alignment. However, from the fact that the structures are not in alignment this would hardly be expected.

Considering all of the folds regardless of size, there is no notable alignment of the individuals and no area in which they are much more numerous (Figure 3). But if only the larger ones, those with an inclosed area of one-fourth square mile or more, are considered, they will be found to lie mostly within three fairly well defined areas. Even with these, however, there is no tendency toward individual alignment (Plate II). The western one of these areas is a long narrow belt extending S. 14° W., from the southwest corner of T. 28 N., R. 9 E. The folding is much less marked south of T. 23 N. The second lies about six miles east. It is somewhat broader than the first and almost parallel to it, extending from the state line as far south as has been mapped, probably for some distance into Pawnee county. The third is still broader, is not so well defined and has almost a north-south trend. It lies mostly in Range 11,



GRAPH SHOWING DIRECTION OF AXES OF FOLDS SUFFICIENTLY ELONGATED AND SYMMETRICAL TO SHOW CONCLUSIVELY DIRECTION OF TREND AND NUMBER OF CASES REPRESENTED. ANGLES ARE MEASURED COUNTER-CLOCKWISE FROM AN EAST-WEST LINE.

FIGURE 2.

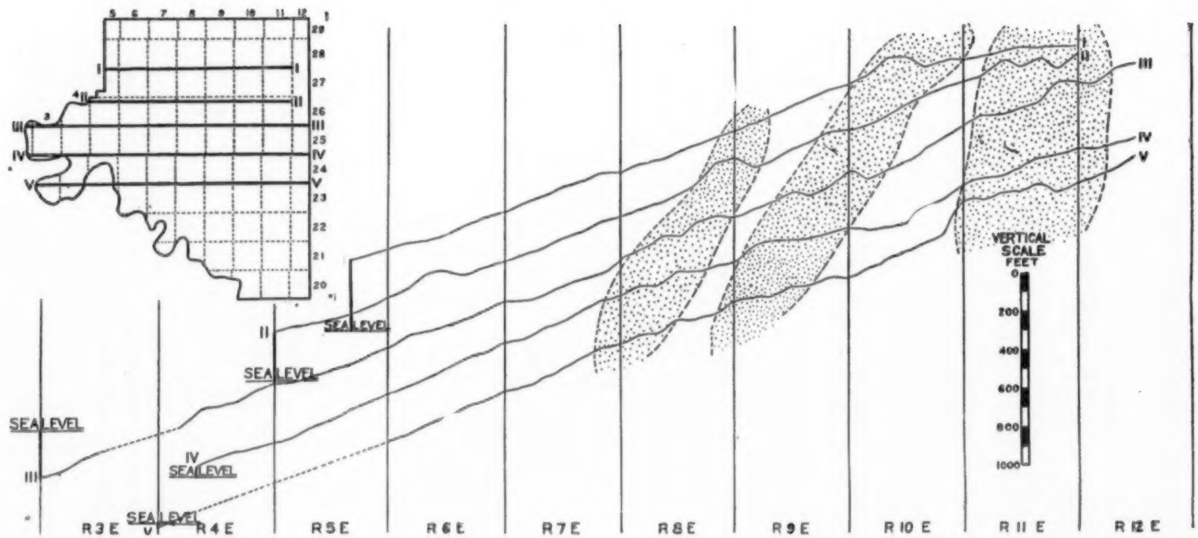


PLATE II

EAST-WEST STRUCTUAL PROFILE ACROSS OSAGE COUNTY.

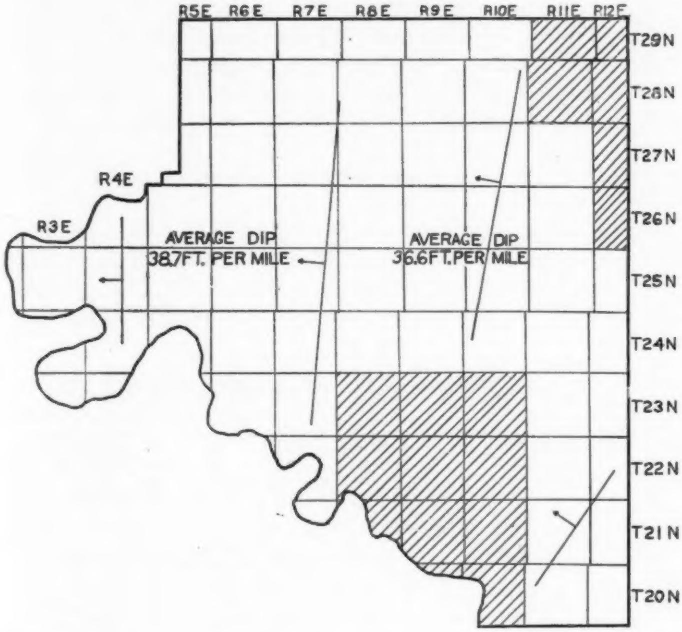


FIGURE 3. Map showing the general strike and dip of surface rocks in Osage county.

and extends both north and south as far as the territory has been mapped.

The statement has been made that the folds lie along larger or master folds, but east-west structure profiles of the strata do not show the presence of such folds (Plate II). The profile within the dotted lines is that part which is through the areas of disturbance. While these parts of the profiles are irregular, it will be noticed that there is no one irregularity which is common to all the profiles within any one area such as would suggest the presence of such master fold. Further, if these master folds did exist it would be expected that the individual folds would be in some alignment which, as shown above, is not the case.

The most notable feature of these areas of disturbance is the faults. From Figure 4 it will be noted that the faulted areas can be quite definitely outlined, especially the middle and western ones. Investigation of these faults reveals a number of interesting facts.

The strike of the faults with few exceptions is northwest-southeast. When the angles of these strikes are measured there are two directions found to be more frequently represented. One is N. 26° to 35° W., and a much smaller group which strike N. 11° to 20° W. (Figure 5).

Each of the groups has areas of predominance. The first is predominant in T. 24 N. and 25 N., R. 8 E. and 9 E., and in two very much smaller areas, one of which is in T. 28 N., R. 9 E., and other in T. 23 N., R. 11 E. The areas of predominance of the second

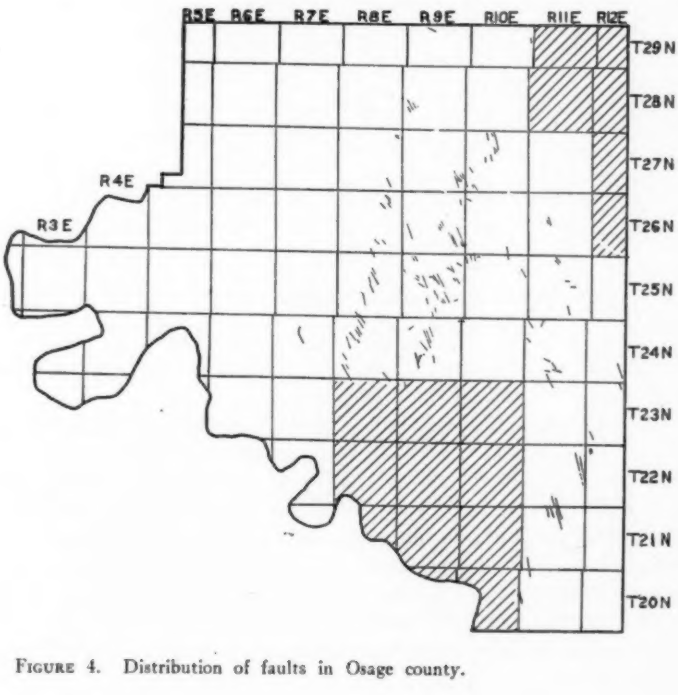
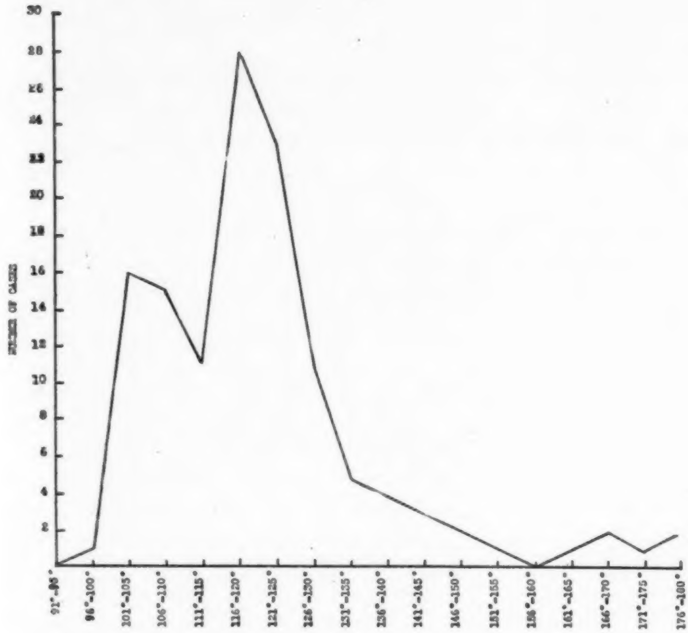


FIGURE 4. Distribution of faults in Osage county.



GRAPH SHOWING DIRECTION OF STRIKE OF FAULTS AND NUMBER OF CASES REPRESENTED.

ANGLES ARE MEASURED COUNTER-CLOCKWISE FROM AN EAST-WEST LINE.

FIGURE 5.

group are not as extensive nor as well defined. The principal one is a long narrow belt extending S. 25° W., from the north side of T. 23 N., R. 12 E. A second one is in the north side of T. 26 N., and south side of T. 27 N., R. 10 E.

The faults with the upthrow to the northeast and those with upthrow to the southwest are about equal in number, and neither has any notable areas of predominance. The amount of throw is in most cases quite small. At least 53 per cent have a throw of less than 10 feet, 70 per cent a throw less than 20 feet, and 82 per cent a throw less than 30 feet. The average amount of throw is a little

larger in the eastern part, but there are no areas in which the faults with a large amount of throw are notably frequent. So far as can be learned the faults are all normal.

In conclusion, the faults and important folds are not distributed at random but lie in zones, the recognition of which should be an aid in the guidance of future prospecting.

GEOLOGICAL STRUCTURE OF EASTLAND AND STEPHENS COUNTIES, TEXAS

H. H. Adams

The greatest benefits derived from petroleum geology have come from a study of details. Theories have furnished a basis for investigation but nothing tangible has been accomplished without detail work. In Eastland and Stephens counties, Texas, the detail workman has made geology worth while. Unfortunately those who have constructed theoretical sections through various areas without study of details, and have advised development accordingly, have hurt petroleum geology in the eyes of the operator.

Detail work has established certain definite rules in Eastland and Stephens counties that have been of inestimable value to the operator who followed them. It has laid a foundation for projecting and extending subsurface structures ahead of development after the field was opened. The detailed subsurface work although a sort of *post mortem* is a key to the interpretation of the surface structures. An effort is made in this paper to show the practical application of detail work. The writer hopes to raise questions and to bring out new facts concerning this field. There is enough known by geologists here present to make a very complete report were it all assembled.

The accompanying map of Stephens and Eastland counties shows surface contours on a considerable territory, and subsurface contours on a few areas where typical conditions exist. The outstanding surface structural features are: (1) there are no large areas of normal dip; (2) there are many plunging anticlines, but an almost complete absence of closed anticlines of importance; (3) the major anticlines are rather regularly flanked by large synclinal areas; and (4) there is little faulting, except in one small zone between Ranger and Desdemona.

H. H. Adams, Ranger, Texas.

SURFACE STRUCTURE

The normal dip of the surface beds in this area is to the northwest at the rate of 45 to 65 feet to the mile. The dip varies so much in these counties (all the way from 0 to 200 feet in the mile) that a large area must be considered to establish the normal dip.

The plunging anticlines, or "noses" as they are commonly called, cannot all be grouped along definite lines, but the larger and more clearly defined ones can. There is a line of folding that extends through the Ranger field to the northwest. This is not a regularly uniform anticline but a series of plunging anticlinal "noses" and small terraces. Immediately north and east of this line is the most clearly defined anticline in the two counties. It passes through the Cotton Plant and Parks fields and is closely parallel to the axis of the Ranger structure. North of this is another line of folding nearly parallel to the other two. It begins in the neighborhood of Caddo and runs north of Breckenridge. This one, however, is considerably broken and in one place, about half way between Breckenridge and Caddo, there is a sharp syncline that breaks through it. These are the principal structures shown by the accompanying map. The same conditions exist in the Mormon and Rising Star areas. It must be clearly understood that these anticlinal areas are quite irregular and must be worked out in a large way in order to establish them.

Between the anticlinal areas there are some very pronounced synclines. The syncline in the Wayland region, between the Ranger and Breckenridge structures, is the most prominent. There is also a synclinal area between Desdemona and Ranger and between the Caddo - Breckenridge structures and the Parks - Cotton Plant structures. The last synclinal area is less clearly marked than the other two.

On a line between Desdemona and Strawn there is an area of considerable faulting. As far as has been determined this area runs in a line a little south of west. It is neither parallel to nor at right angles to the general line of folding. The district offers to the geologist a very interesting problem, but the writer has not done sufficient work in it to be able to give an opinion as to the cause or the effect of the faulting.

The surface structures that are shown on the map were the

first evidence that led to the careful detail work which has been done by various organizations. They led to considerable discussion and disagreement among geologists as to whether they were of any value to the oil operator, since production was found in small surface synclines as well as small surface anticlines. The relation of these smaller structural features to the larger anticlinal areas had not yet been worked out.

SUBSURFACE STRUCTURE

The angular unconformity between the Bend series and the overlying formations is well established and calls for no discussion. It is generally accepted that there is also an erosional unconformity, but the writer believes that the first Black lime, encountered in the Stephens county fields, pinches out to the east and south and is replaced by shales.

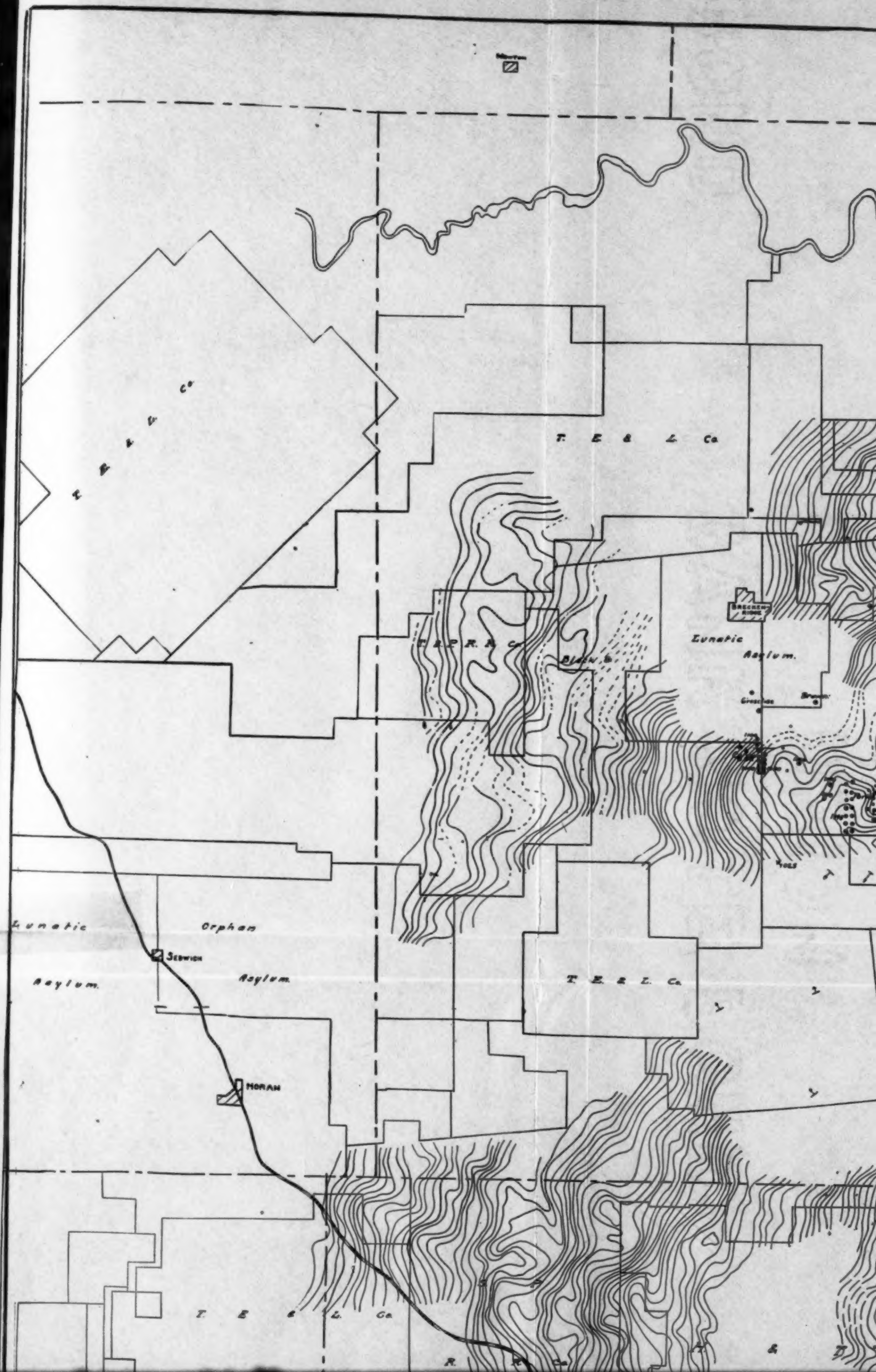
It is well known that logs vary greatly according to the interpretations of drillers, but there are a few facts that can be relied upon in a study of logs in this field. Drillers always know when they get oil, or gas, or salt water, or when they are in a hard or soft formation. With these facts in mind a check can be made and fairly reliable results obtained. In the Jones well No. 2 the first Black lime was encountered at 1,450 feet below sea level. At 300 feet below this point another Black lime of considerable thickness was encountered, and at 180 feet below this production was found. This log agrees with the great majority of logs in this area. It is about 500 feet from the first Black lime to the pay sand. There are four very definite horizons in the Black lime: (1) the top of the first Black lime, or Breckenridge lime; (2) the top of the second Black lime, or Ranger lime (here 6 5-8 casing is usually set); (3) the Gray lime, which is about twenty feet thick and lies close above the Ranger sand; and (4) the Ranger sand. Where wells extend to the Ellenberger, the interval is very regularly 300-450 feet. There are very few logs in which one of these horizons cannot be definitely identified, when the entire Bend formation has been drilled.

Practically all the members of the Bend series have been penetrated in the Winston, Proctor and Veale wells in Stephens county. The uppermost Black lime is now commonly called the Breckenridge lime by operators in the field. The pay sand in the Veale well in Stephens county is the Ranger sand. South of Stephens county the

Breckenridge lime gradually becomes thinner and pinches out. In the Desdemona district it is entirely absent. The pay sand in Desdemona is the Ranger sand. East of Stephens and Eastland counties the Breckeridge lime apparently grades into black shales and a part of the black shale that overlies the Black lime encountered in Palo Pinto and Erath counties is very probably the stratigraphical equivalent of the Breckenridge lime. The undoubted thickening of these shales in that direction may be accounted for in this way.

Beyond doubt the Bend series dips quite rapidly to the west and to the north from the vicinity of Ranger. It also dips to the east, as is shown by the Oaks well drilled south of Mineral Wells. In the east side of Eastland and west side of Erath counties corelations have been made on the first Black lime encountered in the wells, and since the Breckenridge lime is present in the Ranger field and is absent in Erath county, the writer believes that mistakes have been made by correlating the upper or Breckenridge members with the lower or Ranger members of the Bend series, so that more east dip is shown in this area than really exists. The log of the Allen well shows the Ranger sand to be slightly higher there than it is at Ranger in the Vick well. The Vick well is lower than the average in the Ranger field. South of Mineral Wells in the Oaks well, the Black lime, or what is regarded as the Black lime, is much lower than it is in the Ranger field. This is evidence of the Bend Arch, which has been so widely discussed. Whether the Black lime in the Oaks well represents a point on the regularly dipping east flank of the Bend Arch, or whether it is a point in a large local syncline, is still an open question since drilling in this part of the state has not been extensive enough to prove the point entirely. There is certainly some kind of an arch that will be definitely worked out within the next two years. The writer believes that further data and study upon the Bend Arch will show that it is a very much more gentle fold than is the present general conception.

It is with local structural conditions in the Bend in these fields that the writer is particularly concerned. They are much more sharply defined than the associated surface one. Several large, clearly defined structures have already been worked out on the Bend. The best known of these is that at Desdemona. The Desdemona field lies on a large closed anticline in the Bend, with considerably more than 100 feet of closure.

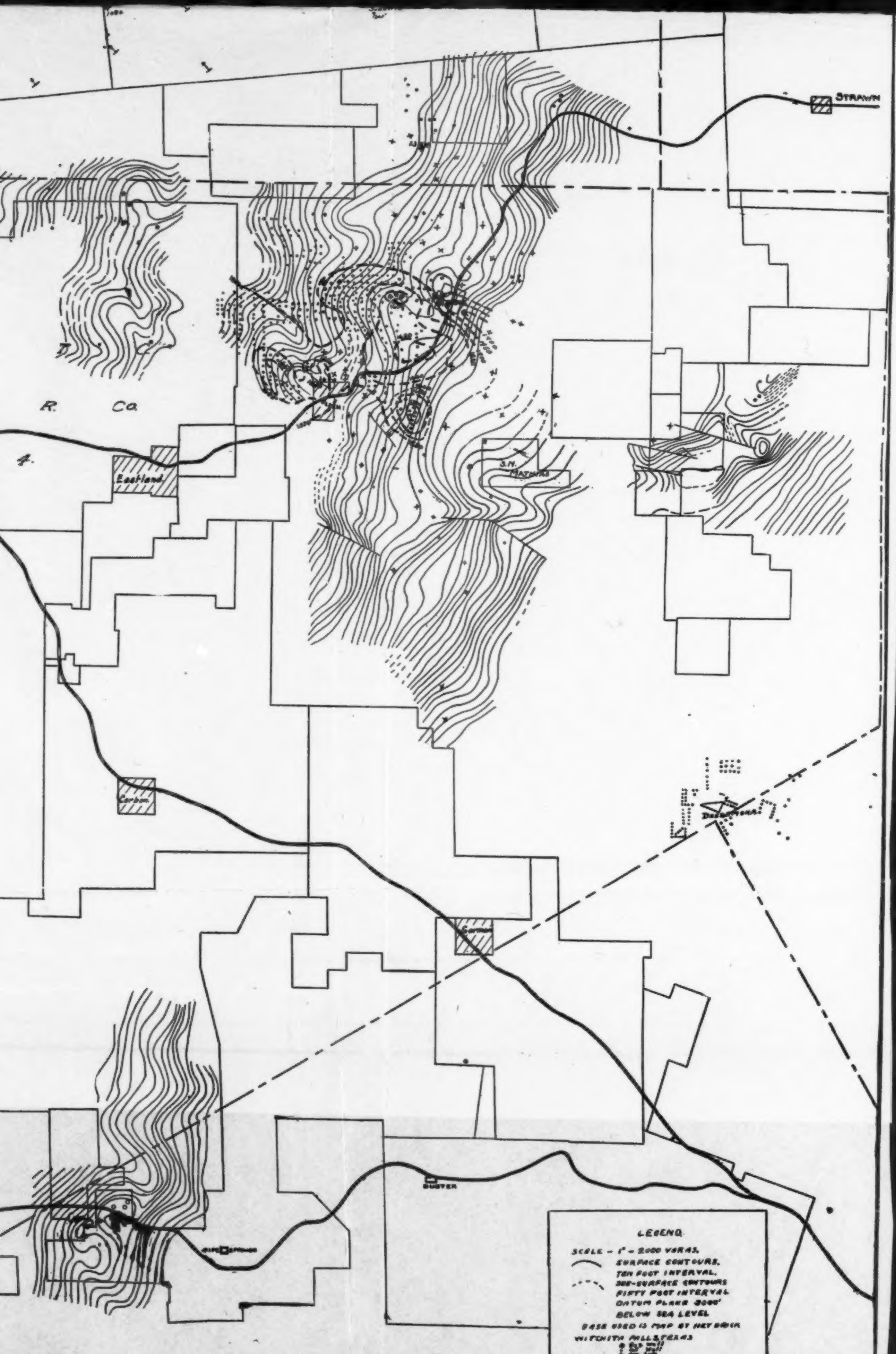


T. E. & L. Co.
T. & P. R. R. Co.
Lunatic
Asylum.
Orphan
Asylum.
SEDWICK
MORAN
Lunatic
Asylum.
T. E. & L. Co.
T. E. & L. Co.

Caddo Village
S. P.
R. R. Co.
Block 8.
T. & P.
R. R. Co.
Block 5.
Caddo
T. & P.
R. R. Co.
Orphan
Block 4.
Knott
1240
T. & P. R. R. Co.
Block 6.
Jackson
Bradford
1170'
Strawn


MORAN
T E & L. Co.
R R Co.
H & T
R R
Blk 4.
Bayland Orphan
Asylum
H & T C
R R Co
Blk 3
A. T.
Burnley
Camel Co
School Lands
MAP ILLUSTRATING STRUCTURAL CONDITIONS
IN EASTLAND AND STEPHENS COUNTIES, TEXAS.
ADAMS & REYNOLDS
RANGER, TEXAS.

PLATE III.


STRAWN
R. Co.
Eastland
Carbon
Desdemona
Gorman
S.N. Matthis
LEGEND
SCALE - 1" - 2000 VARAS.
SURFACE CONTOURS.
TEN FOOT INTERVAL.
SUB-SURFACE CONTOURS
FIFTY FOOT INTERVAL
DATUM PLANE 3000'
BELOW SEA LEVEL
BASE USED IS MAP BY HEYDRICK
WITCHITA FALLS, TEXAS

ATE III.

In the Ranger field there is a very clearly defined anticlinal terrace in the Black lime. This terrace is elongated to the southeast and takes in the Brewer pool. The terrace is quite irregular and is deeply cut by a syncline from the southwest and also one from the east at the south end of town. There is less dip on the west side of this structure than one would suspect, from the surface contours.

A large anticlinal terrace is present in the Black lime with its axis passing through the Cotton Plant and Parks field. Due south of this there is a deep broad syncline in the Wayland area. This syncline comes in from the west and reaches nearly half way across the county.

North from Cotton Plant there is another clearly defined anticlinal terrace. This passes through the Swenson property and is about six miles long. Immediately west of the north end of this anticline is a very pronounced syncline.

There has not been enough development in the Breckenridge area to allow a determination of subsurface conditions there, but in all probability the conditions are similar to those in the Cotton Plant-Parks district.

RELATION BETWEEN SURFACE AND SUBSURFACE STRUCTURE

The relation between surface and subsurface structures are now well established in Stephens and Eastland counties. Surface terraces are expressions of subsurface terraces, and so on. The relation of the subsurface contour map of the Ranger district to surface strucure, brings this out very clearly. The heavy broken lines (Plate III) are subsurface contours with a 50-foot interval, and the solid lines are the surface contours with a 10-foot interval. The surface contours show a plunging anticline beginning at the Duffer lease, just west of Ranger. The subsurface contours show a small closed dome immediately beneath this lease. This lease is the largest gas producer from the Black lime in the field. The Ranger sand is 1,886 feet below sea level at the highest point on the lease. The Black lime here is higher than at any other point in the Ranger field north of the Brewer pool where it is practically 40 feet higher. The surface structure is also the most clearly defined plunging anticline in the Ranger area. In the Connellee area there is a well defined surface "nose" and immediately beneath it there

is a closed anticline in the Black lime. Between the Duffer lease and the Brewer pool there is a well defined terrace on the surface and immediately beneath it and a little to the west is a large anticlinal terrace in the Black lime. In the northwest quarter of the Blundell survey, just north and west of the town of Ranger, there is another small, rather round, surface terrace and beneath it there is a small dome in the Black lime. In the south edge of the town of Ranger there is a very deep, subsurface syncline. There is some question as to the accuracy of the data since complete logs were not available, yet it is certain that this is a synclinal area. The surface here also shows a syncline.

The Brewer pool, which is one of the chief producing areas in the field, is on a very prominent subsurface dome. This is well down over a very pronounced surface anticline, passing through the S. N. Mathias survey. The structural conformity between surface and subsurface here is not so clear, but there is some question about the surface contours. The Canon lime in this area is about 40 feet thick close to the Brewer wells and the same beds a mile and a half to the south pinch down to less than 10 feet. Since the beds are difficult to follow the surface contours may not be correct.

In the Parks field in Stephens county the same conditions exist that have just been described in the Ranger area. There is a plunging anticline at the west end of the Cotton Plant-Parks structure on which the Stoker, Davis, Brooks and Lauderdale wells are located. The subsurface structure shows this area to be a few feet higher on the Black lime than the area just east where the Parks wells are located. The Black lime dips from this area to the south into the Wayland syncline for at least 100 feet. There is a small closed structure in the Black lime just beneath the plunging anticline mentioned.

Similar conditions exist in the Cotton Plant area and are almost identical with the conditions just described in the area in the west part of the Cotton Plant-Parks anticline.

There is a remarkable relation between surface and subsurface structures. Terraces shown in the subsurface map lie slightly to the north and west of surface terraces. Anticlinal domes in the Bend are expressed by plunging anticlinal "noses" on the surface. Broad surface terraces that are flat, or show reverse dip, show a depression in the Black lime.

RELATION OF STRUCTURE TO PRODUCTION

A study of the results of development in these fields with the associated surface structural conditions has established a definite connection between areas of gas production and large and small oil production, and the accompanying structural conditions.

Terraces have given few commercial wells. The wells around the town of Ranger and along the railroad at Ranger, on the terrace east of Olden and on the terrace east of the Parks field gave no production, or only slight production, except in initial wells, like the Parks No. 1 and the McCleskey No. 1.

Large synclines are non-productive. To date only one small well has been developed in the synclinc between Ranger and Desdemona. All the tests made so far in the Wayland area have proved dry. The large general syncline north of the Ranger field, on the county line, has proved non-productive.

Areas of normal dip provide small and short-lived wells, as in the Minnie Sibley survey.

At the breaks between the terraces and the fast dipping sides of the anticlines, in some cases gas and in others oil is found. The gas wells are in most instances on small domes located on the line of break.

From the line of break to half way down the sides of the anticlines the largest production has been consistently found. Examples are the Norwood, Emma Terrell and Roper at Ranger, the McCauley and Swensondale at Necessity. These wells have been remarkable for their amount of production.

From half way down the sides to where the anticline gives way to the terrace on the west have been found areas of big production, as the Pleasant Grove area and the Stoker area. This part of the structures has not been universally good and should not be as favorably regarded as the upper half.

Small synclines located on the sides of the large anticlines are giving large production. The Fincher No. 2, the Carey No. 1, the Sandidge No. 1 and the Copeland wells are instances of good production in a small local syncline on a large anticline.

There are a few exceptions to this rule. The same rules of accumulation of oil and gas that are universally accepted apply to the Bend structures in this field.

DECLINE OF PRODUCTION

Production in the Ranger and Desdemona fields has fallen off very rapidly. This rapid decline is largely due to the methods of development. Too many wells were drilled and no effort was made to conserve the gas pressure. In Desdemona where the larger companies had few leases, the smaller operator rushed in and drilled four wells to the acre in the townsite. Outside of the townsite drilling was less intensive, yet for some distance out it averaged at least one well to three acres. The force required to lift oil three thousand feet is considerable and is dependent entirely on gas pressure or artificial means. This pressure was wasted rapidly by allowing the gas wells to run wide open in order to have them blow into oil wells. It seems to the writer that one well to 35 acres is sufficient in this region.

The producing formation varies from a hard lime to a close-grained sand. It requires a great gas pressure to move the oil in the sands or lime, and when the gas pressure is exhausted wells cease to flow, and in many instances do not make pumpers. The lime wells are notoriously poor pumpers.

It is a well known fact that when the Duffer gas well was drilled in west of Ranger, all the wells in the neighborhood were almost immediately affected. An examination of pipe line runs from the Jones-Bartles wells on the Gholson lease, the Woods, the Jones and other surrounding leases will show most conclusively that the waste of pressure alone caused a heavy loss to all the surrounding leases.

The discovery well in each pool or separate locality has uniformly held up the best. The Norwood No. 1, the Connellee No. 1 and the McCleskey No. 1, in Eastland county, the McCauley No. 2, the Swensondale No. 1, and the Ward No. 1 are good examples. These wells had no competition and had the entire gas pressure to establish lines of flow.

The amount of oil per acre is still an unknown quantity. Rough estimates have been made, but the best information at hand is on a few leases, such as the Taylor lease west of Ranger, which has made over 8,000 barrels per acre and is still producing. This lease was surrounded by wells and probably drew little from the neighboring leases. This seems to be a fair example for this part of the field. The general average for the field will be much less than this.

There are other leases, however, that have produced considerably over 8,000 barrels according to reports.

One fact, in conclusion, is that the Ranger sand has not been developed in the Stephens county field except in a few wells. The production is from the top of the Breckenridge lime,which is 500feet above the Ranger sand. The Ranger sand is the best producer in the Bend series, and is worth thorough development in Stephens county. The Breckenridge lime in the west Ranger field has also been neglected. It responds to shooting in a remarkable way in Stephens county. Wells that are apparently dry are shot into big producers. It should also respond to a shot in the Ranger area.

THE ILLINOIS SECURITY LAW

F. W. DeWolf

INTRODUCTION

The Illinois Security Law, administered by the Secretary of State, is probably of interest to this Association because it prescribes the conditions under which securities of oil companies may be offered for sale in the State. Applications received since passage of the Act, June 10, 1919, up to March 10th of this year have been based on properties or leases located chiefly in Texas, Oklahoma, Kansas and Louisiana. Since appraisal of properties by competent men is required, a brief explanation of the law and of progress under it may call forth interesting and helpful discussion at this meeting.

The purpose of the law is to protect the public from fraudulent securities, but with the minimum inconvenience to sellers of sound securities. For the purposes of the Act securities are divided into Classes A, B, C, and D, and Classes A and B are exempted from the provisions.

CLASSES AND EXEMPTIONS

Class A includes those securities, the inherent qualities of which assure their sale without fraud; as, for example, those issued by the government, or any agency having power of taxation; or by a public utility under regulation by law; or any security authorized to be dealt in on the stock exchange of New York, Chicago, Boston, and some other cities. Some other kinds of securities also are defined as in Class A.

Class B comprises securities sold by the owner for his own account when not made in the course of continued and repeated transactions; or increased capital stock of a corporation sold to its stockholders under specified conditions; or securities of any bank, trust company, insurance company organized under Illinois or United States laws, or doing business in Illinois under State supervision. Some other varieties are also enumerated.

F. W. DeWolf, Illinois State Geological Survey, Urbana, Ill.

Class C securities must be based on established income, and in general are based on a business which has been in continuous operation at least two years, and which has shown net profits of a specified magnitude in comparison with all outstanding interest-bearing securities, or in comparison with dividends on preferred or common stock. Such securities may be sold only under specified conditions.

All securities other than those falling in Classes A, B and C are known as Class D and must be labeled "speculative securities." Into this class fall most of the oil-company securities so far presented for consideration by the Secretary of State. Such securities may not be sold or offered for sale until certain statements and documents have been scrutinized and filed by the Secretary of State. If the statements are inadequate, or evasive, or if the sale of securities based upon the plan or scheme evidenced by the documents would in the opinion of the Secretary work or tend to work a fraud upon the purchaser, the Secretary must refuse to file the statements.

REQUIREMENTS FOR CLASS D

Among the statements and documents required covering Class D securities may be mentioned the following: (1) A description and amount of the securities intended to be offered for sale; (2) If the issuer is a corporation, a certified copy of the charter or articles of incorporation and by-laws; (3) If the issuer is a firm, trust, partnership or unincorporated association, a copy of the articles of partnership, association or trust agreement; (4) The names, addresses and prior occupations during a period of not less than ten years prior to filing such statement (giving details as to time, place and address of employer and reasons for discontinuance of employment) of the officers, directors or trustees of the issuer, if it be a corporation, or of the persons composing the issuer, if the issuer be a non-incorporated association; (5) A description of the nature of the industry engaged in, or intended to be engaged in, and the approximate time when such industry was or will be established; (6) An inventory showing the assets of the issuer; (7) An appraisement of the assets of the issuer; (8) A statement in detail of the gross income of the issuer and the source or sources thereof, and of its operating and other expenses for a period of twelve months prior to the date of filing such statement, or for the period of the existence of the issuer if

less than two years prior to the date of filing; (9) A copy of the most recent balance sheet of the issuer, showing the financial condition of the issuer at a date not more than thirty days prior to the date of filing, and giving an analysis of surplus account from inception of such issuer; (10) A copy of the mortgage, trust deed, indenture or writing securing the securities, (or) whereunder the same are issued, if any such instrument there be; (11) A copy of the form of the securities intended to be offered; (12) A copy of any and all subscription blanks to be used in the sale thereof, which subscription blanks shall have printed thereon, "These are speculative securities;" (13) A statement as to the manner in which the securities are to be offered and sold; (14) If the securities be intended to be offered and sold by the issuer through solicitors, agents or brokers, an irrevocable contract executed by each such solicitor, agent or broker authorized to offer or sell such securities by or on behalf of the issuer to the effect that the issuer will receive in cash not less than 80 per cent of the proceeds of each sale of the securities without deduction for any commission or expenses, directly or indirectly, and without liability to pay any sum whatsoever as commission or expenses or for services in and about such sale; (15) A summary of the material facts disclosed by the preceding statements; (16) Such other facts relative to such securities as the Secretary of State shall prescribe.

With the statement there shall be filed an inventory, in such detail as the Secretary of State shall require, showing the assets of the issuer as of a date not more than thirty days prior to the date of filing thereof. Such inventory shall be accompanied by an appriasement made by a qualified person or persons showing the value of the assets described in such inventory. The person or persons making such appriaisement shall state in such appraisement the character and nature of their experience and their qualifications to value such property, and all the facts or considerations on the basis of which their estimate of values is predicted. Such appraisement shall be verified by the oath of the person or persons making the same.

If the statement as to securities in Class D shall disclose that any of such securities shall have been or shall be intended to be issued, for any patent right, copyright, trade-mark, process or good will, or *for promotion fees or expenses*, or for other intangible assets, the amount and nature thereof, shall be fully set forth, and securities issued in payment of such patent right, copyright, trade-mark, process

or good will, or for promotion fees or expenses, or for other intangible assets, shall be delivered *in escrow* to such bank or trust company as shall be designated by the Secretary of State, under an escrow agreement that the owners of such securities shall in case of dissolution or insolvency not participate in the assets of the corporation until after the owners of all others securities have been paid in full. Such escrow agreement shall remain in full force until the securities of the issuer thereof are qualified under Class C hereof.

Other requirements are made of salesmen or brokers; and there are provisions for getting service on the issuer in case of suits arising out of the sale of the securities. There are severe penalties for violation or evasion of the Act and for perjury in connection with it. There is provision also for stopping the sale of securities in case after filing facts or conditions arise which indicate that further sale would tend to work a fraud.

APPRAISALS

It is evident that many of the appraisals first submitted were based on nothing better than speculative exchange prices, or opinions of dealers. Recently the Secretary has prepared an outline of essential information to be embodied in reports of experts and has selected a number of petroleum geologists and engineers whose reports will be especially acceptable. The information required is much the same as that outlined in Schedule N of the Treasury Department, for arriving at the value of a property on a given date. It includes maps and statements covering location, land data, well data, production data, oil reserves, casing-head gas, operating data, inventories, and summary of the valuation. The cost of appraisal is borne by the applicant.

SUMMARY OF OPERATIONS

A summary of the operation of the law as prepared by the Secretary of State, March 10th, shows authorized issue in Illinois of Class C, approximately $137,000,000, and of Class D, $18,000,000. Refused: Class C, $2,250,000, and of Class D, $44,000,000. The number of cases received was 400, of which 177 were refused and 213 filed; of those filed 125 were in Class C and 88 in Class D. The writer is unable to state the number of oil companies that attempted to qualify, but on February 26th about 50 such applications had been received and only five approved for filing.

PRE-PENNSYLVANIAN OIL AND GAS HORIZONS IN KAY COUNTY, OKLAHOMA

F. L. Aurin

INTRODUCTION

In this paper the writer wishes to present some interesting features of recent development in Kay county, Oklahoma, in as far as its relation to the subsurface stratigraphy of the lower Pennsylvanian, Mississippian and older sediments has been revealed by some of the deep wells drilled. This paper will not go into details concerning the Pennsylvanian or the Mississippian in areas other than Kay county, except when they have a direct relation to this subject. The writer is permitted to publish this paper through the courtesy of E. W. Marland and F. P. Geyer, President and Chief Geologist, respectively, of the Marland Refining Company. Others who have assisted and given valuable suggestions are E. C. Parker, A. W. McCoy and E. A. Trager.

HISTORY OF DEVELOPMENT

There are four producing areas in Kay county, the most important one being the Ponca City field, which is located several miles southwest of Ponca City. The Blackwell field is located about seven miles northeast of Newkirk, the Newkirk field about six miles southeast of Newkirk, and the Northeast Newkirk field, three miles northeast of the same town.

All of the early production in the Newkirk field was in the shallow 900-foot sand, which is approximately the horizon of the Elgin sandstone. In the Ponca City field most of the production came from the 1,500-foot sand. Both of these sands are in the upper part of the Pennsylvanian. In the Blackwell field shallow gas was discovered at a depth of 700 feet, which is in the Permian. Later developments in these fields found deeper productive sands in the Pennsylvanian

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F. L. Aurin, Ponca City, Oklahoma.

and also in the Mississippian. During 1914, a deep oil sand was discovered in the Blackwell field at a depth of 3,300 to 3,400 feet, which is thought to be in the Mississippian or even lower, and in the Newkirk field production at a depth of 3,200 feet, which is above the top of the Mississippi lime. In the Ponca City field production was found at a depth of 3,650 and 3,950 feet, the former being in the top of the Mississippi lime and the latter 300 feet stratigraphically below the top. The Marland sand or "3,900" sand is at least Mississippian and may possibly be Devonian. A study of the subsurface stratigraphy of Osage county and surface sections of eastern Oklahoma was made in an attempt to establish the above correlations.

DEVONIAN AND MISSISSIPPIAN IN EASTERN OKLAHOMA

In eastern Oklahoma the best section is that on Spavinaw Creek in Mayes county. Above the Spavinaw granite there are several hundred feet of Cambrian or Ordovician limestone, the top of which contains considerable brecciated chert. The Chattanooga shale, which is black, lies unconformably above this limestone. The Boone chert, which has a thickness of about 300 feet, lies above the Chattanooga, and is separated from it by a thin bed of limestone and a thin bed of green shale. The Fayetteville formation, which is principally a black carbonaceous shale, overlies the Boone. The remainder of the Mississippian section will not be given in this paper as it has no important relation to this discussion.

PRE-PENNSYLVANIAN HORIZONS IN OSAGE COUNTY

From the surface outcrops in eastern Oklahoma the Boone chert can easily be traced westward from subsurface data. In the extreme eastern part of Osage county the top of the Mississippi lime or Boone chert is found at depths ranging from 1,400 to 1,800 feet. The average interval between the Fort Scott or "Oswego" lime and the Mississippi lime (Boone chert) is about 550 feet, while farther west this interval gradually decreases to about 350 feet in western Osage county. In the Ponca City and the Newkirk fields this interval is about 350 feet, while in the Blackwell field it has not been definitely determined, for there is a very abrupt change. This point will be discussed later.

In Osage county there are many wells producing from the Mississippi lime. Most of this production, however, is from the top, especially in the extreme northern and western parts. The source of the oil is from the black shales above it. Most of the wells producing from this horizon have initial productions ranging from 25 to 100 barrels. In the Pearsonia field in western Osage the second oil well had an initial production of 7,000 barrels. Another sensational producer was that drilled by the Minnehoma Oil Company, in the Myers district, which had an initial production from the top of the Mississippi lime, estimated at 15,000 barrels. After shutting this well in for a few days it was opened up and made considerable water but very little oil. Later it was revived to the average size well producing from the top of the Mississippi lime. Many other wells could be mentioned as good producers from the top of the Mississippi lime.

In several localities production has been found at various depths in the lime. In Sec. 13, T. 21 N., R. 10 E., several wells have been drilled over 300 feet into the lime and found production. According to the logs the top of the lime is gray and cherty. Downward it changes into a dark, cherty limestone. At a penetration of 355 feet a bed of black shale was encountered beneath which was a productive oil sand.

The Marland Refining Company found production at two different horizons in the Mississippian in Sec. 13, T. 22 N., R. 8 E. The top of the lime is encountered at an average depth of 2,320 feet. The same characteristics and gradation from gray, cherty limestone to dark, cherty limestone are found here. There is a producing horizon at the top of the lime and another about 300 feet below the top. The deepest horizon occurs just beneath or a few feet below a thin bed of black shale.

In western Osage county most wells have been drilled to the Mississippi lime, one being drilled to a depth of about 700 feet below the top. Samples of the well cuttings show the following characteristics:

3154′	Top Mississippi lime, typical Boone chert.
3154-3190	Gray, cherty limestone.
3190-3364	Dark, cherty limestone.
3364-3415	Samples lost.

3415-3480	Good samples not obtained, probably gray lime and some black shale.
3480-3510	Hard, white sand.
3510-3570	Gray, sandy shale.
3579-3580	Black shale and gray sand.
3580-3590	Gray limestone.
3590-3630	No sample.
3630-3640	Shale and gray lime.
3640-3660	Cherty lime.
3660-3680	White sand.
3680-3705	White, sandy lime.
3705-3716	Gray lime and sand.
3716-3725	Gray lime.
3725-3845	Brown, blue and gray lime.

In the above record the material from 3,154 to 3,190 feet is typical Boone chert, and below the latter depth the dark cherty material continued to a depth of 3,415 feet, as in the case of the other wells. Below the lime there are several alternating beds of black shale and white sandstone extending to a depth of 3,580 feet. From this depth to 3,845 feet, the bottom of the hole, the formation is a bluish-gray limestone with sandy members at intervals.

In Sec. 11, T. 25 N., R. 3 E., western Osage county, the Marland Refining Company encountered a productive horizon in the top of the Mississippi lime at a depth of 3,550 feet. The top of the lime was found at 3,500 feet.

KAY COUNTY

In the Ponca City field the top of the Mississippi lime is found at an average depth of 3,650 feet and almost all wells drilled to it are productive. The character of the Mississippian is very similar to that found in Osage county. The top is usually a sandy or broken chert and is succeeded below the dark, cherty lime zone, which continues to a depth of about 3,920 feet. Below this zone 10 to 30 feet of black shale is found, which in turn is succeeded by a productive oil sand, called the Marland sand. No wells in this field have been drilled far below this sand. The production from the top of the Mississippi lime varies from 50 to 150 barrels, while several wells in the Marland sand have had an initial production as high as 2,500 to 3,000 barrels. One of the most remarkable wells in this field is the Brett No. 6, which was completed June 21, 1919, and had an initial production of 2,000 barrels. After a period of nine months it was

still producing 1,000 barrels daily. The total production from this one well has amounted to over 300,000 barrels during this time.

NEWKIRK FIELD

In the Newkirk field the top of the Mississippian is found at an average depth of 3,250 feet. There is a sand, occurring at about 3,100 feet, which is productive in Sec. 15, T., 27 N., R. 3 E., and several other places in this locality. This sand is 150 feet above the lime and is separated from it by shale and sandy lime. The initial production ranges from small wells to those having a production over 1,000 barrels. No production in commercial quantities has been found in the top of the lime. The lime has the same characteristics as are found in the Ponca City field and western Osage. The gray cherty limestone grades downward into the dark cherty zone. The black shale below the lime as found in other localities occurs here at an interval of about 300 feet below the top of the Mississippi. A sand is also found below the black shale. Below this sand a grey siliceous limestone occurs and continues to a depth of at least 4,250 feet, which is the depth of the deepest well drilled in the Newkirk field.

NORTHEAST NEWKIRK FIELD

In the Northeast Newkirk field the top of the Mississippi lime is encountered at a depth of 3,400 feet. About 150 feet above it is a gas sand, which is at about the same stratigraphic position as the oil sand which occurs above the lime in the Newkirk field. In the Hebeison well No. 1, drilled by the Marland Refining Company, in Sec. 17, T. 28 N., R. 3 E., a productive horizon was encountered in the top of the Mississippi lime at a depth of about 3,400 feet. The characteristics of the lime are the same as in the other areas mentioned. The black shale with the sand beneath occurs at the average interval of 300 feet below the top of the lime. Below this sand is the same siliceous limestone as is found in the Newkirk, Ponca City, and Western Osage fields. Samples of this siliceous limestone when first bailed from the well are of a bluish gray color, but soon after exposure to the atmosphere are stained brown by oxidation of pyrite and iron worn from the bit in drilling.

In the Joynson well No. 1, located in Sec. 18, T. 28 N., R. 3 E., the siliceous limestone was found from 3,780 to 4,790 feet, a thickness

of 1,010 feet. Below the latter depth the drill has penetrated 30 feet of quartzite. This material contains much quartzite and some milky quartz stained brown by limonite. In addition to the above constituents a few fragments of weathered feldspar were found in the cuttings. This quartzite would probably be classified as belonging to the Algonkian and it possibly directly overlies the granite. If this well is drilled deeper it is very likely that granite will be found below the quartzite.

BLACKWELL FIELD

In this field greater irregularities occur in the Mississippi lime than any place to the east. As previously mentioned, the interval between the "Oswego" (Fort Scott), and the Mississippi limes in the Ponca City field and Western Osage is estimated at 350 feet. From Ponca City westward this interval increases slightly until in the main part of the Blackwell field, where there is a remarkable sudden decrease, the top of the Mississippi lime occupying about the same stratigraphical position as the top of the "Oswego" limestone. The "Oswego" is apparently not present. Another remarkable feature about the Mississippi lime is that the top of it as represented in the Blackwell field is identical with the lower part of this formation in the Ponca City field, as shown by a comparison of samples of well cuttings. The top of the lime is found at an average depth of 3,300 feet and is for the most part composed of black and gray chert. Most wells show about 50 feet of this material. Below this horizon is a bed of black shale averaging 10 to 15 feet or more in thickness. This is succeeded by 20 to 30 feet of dark, hard sand and chert. It is in the latter horizon or Swenson sand, as usually known, that the deep Blackwell production occurs. Some of the wells in this sand had an initial production as high as several thousand barrels. This productive horizon seems to correspond to the Marland sand (3,900-foot sand in the Ponca City field). Below the productive sand there is a thin break of green shale which in turn is succeeded below by white sand. These are identical with the green shale break and the white sand found in the Newkirk and Northeast Newkirk fields at the same stratigraphical position. Below the white sand in the Blackwell field the siliceous limestone, as found in other fields at this horizon, occurs and continues to a depth of at least 4,385 feet;

a known thickness of 865 feet, as shown by the well cuttings from the East Simmons well No. 1, in Sec. 8, T. 28 N., R. 1 E.

VANSELOUS WELL

Many other deep wells in Kay county could be mentioned, but it is thought that several of these will suffice for the scope of this paper. A deep well was drilled in Sec. 27, T. 25 N., R. 1 E., about five miles southwest of the Ponca City field, to a depth of 4,337 feet. The top of the Mississippi lime was found at a depth of 4,095 feet and was the typical gray, cherty limestone. This was succeeded by dark cherty material to the bottom of the hole. The interval between the "Oswego" and the Mississippi lime is estimated at 435 feet, which is a considerable increase southwestward from the Ponca City field where it is about 350 feet.

NOBLE COUNTY

Another interesting deep well is that of the Humphreys Petroleum Company, in Sec. 20, T. 24 N., R. 1 W., which was drilled to a depth of 4,485 feet. The Mississippi lime was found at an approximate depth of 4,300 feet. The top of the lime was the typical gray, cherty lime and was succeeded below by dark cherty material, as in the other wells mentioned, to the bottom of the hole. A good show of high grade oil was found in the top of the lime. This production was the deepest found in Oklahoma according to depth, but not stratigraphically, as the Marland sand at Ponca City and sands at several other places are below this horizon. This well was later abandoned.

SUMMARY

Most of the production in Kay county and adjoining counties, until a few years ago, was from various horizons in the Pennsylvanian. Some years ago the dead line for production was the Mississippi lime, but since that time energetic operators who had faith in deeper production have been rewarded. The main object of former exploration was to find the Bartlesville sand, but development has shown, together with sub-surface data, that Bartlesville sand does not extend very far westward from a northeast-southwest line through Pawhuska, Osage county, Oklahoma. On account of the decreasing

interval between the "Oswego" and the Mississippian, the Bartlesville sandstone gradually approaches the Mississippian and is cut out entirely by overlap. From the above mentioned line westward there is often a sand in contact with the Mississippian, but it is not the Bartlesville. It is very hard to tell definitely in all cases whether this sand is a product of erosion along the unconformity between the Mississippian and Pennsylvanian or is a sandy phase of the cherty lime. The shales in many cases above the unconformity are black and are the source of the oil found in the top of the lime. Wherever the black shales are in proximity to a reservoir in the sand, the sandy zone of the lime, or a broken and fractured part of the lime, and under certain structural conditions good accumulations of oil are usually found. Especially is this true of the western part of the Osage, which conditions make this area more favorable as a producing area than was formerly thought.

In connection with this paper it might be interesting to note several features of the lower part of the Pennsylvanian in proximity to the Mississippi lime. A coal bed, which is stratigraphically just below the horizon of the "Oswego" lime, is encountered in practically all of the deep wells drilled in the extreme western part of the Osage and in the Ponca City and Newkirk fields.

Another important horizon marker is a thin bed of red shale, which occurs at an irregular interval below the "Oswego" but at a fairly regular one above the Mississippi lime. The average interval, which is composed mostly of black shale, between it and the top of the lime is about seventy-five feet. It is possible that the red shale horizon is indicative of an erosional unconformity. If such should be the case, what is the age of the black shale between it and the Mississippi lime? Is it a part of the lower Pennsylvanian or could it belong to the Fayetteville or Morrow group? Subsequent data may afford means of answering these questions.

The next question is the age of the black shale and associated productive sand, occurring 300 feet below the top of the Mississippi lime. The Boone chert as exposed at the outcrop in northeastern Oklahoma, and as encountered by drilling in Osage and Kay counties, is characteristically a gray Boone chert or cherty limstone. The amount of typical gray Boone chert decreases in thickness westward from its outcrops in eastern Oklahoma, through Osage to Kay county, where in the Ponca City field about thirty feet seems to be

the maximum amount. Below the Boone chert in eastern Oklahoma the St. Joe limestone sometimes occurs and is in turn succeeded below by the Chattanooga shale. In some of the deep wells in Washington county limestone of varying thickness has been recorded in the logs as occurring below the Boone chert.

In the log of the Maggie Thompson well, in Sec. 22, T. 29 N., R. 13 E., black chert and shale occurs below the Boone chert. This formation would seem to correspond to the Chattanooga shale rather than to anything occurring in the known surface section between the Boone and Chattanooga. Throughout Osage and Kay counties, as previously mentioned, there is a black cherty limestone occurring below the typical Boone chert. This might be correlated with the Chattanooga shale, or if it is a part of the Boone chert there has been a distinct change in the lower part of it from its outcrop westward. In Kay and parts of Osage county black shale is usually found below the black cherty zone. This is the black shale horizon occurring above the deep sand (Marland sand) in Kay county. This black shale horizon is tentatively correlated with the Chattanooga shale. The Marland sand is correlated with, or is the stratigraphic equivalent, of the Sylamore member of the Chattanooga.

In eastern Oklahoma the Silurian, Ordovician and Cambrian are represented by the St. Clair Marble, Tyner formation, Burgen sandstone, and an unnamed dolomitic limestone which outcrops at Spavinaw. In practically all of the deep wells in southeastern Kansas and northeastern Oklahoma this section is represented by sandstone, limestone, and sandy limestone. In western Osage county and Kay county, Oklahoma, it is represented by white sand and sandy limestone. The total thickness of this series was found to be over 1,000 feet thick. Only one well in Kay county, the Joynson well, No. 1, in Sec. 18, T. 28 N., R. 3 E., has drilled through this series, the depth of the base being 4,790 feet below the surface. The material encountered below this series was a quartzite of probable Pre-Cambrian age and which is thought to overlie the granite.

AN OUTCROP OF BASIC IGNEOUS ROCK IN KANSAS

RAYMOND C. MOORE AND WINTHROP P. HAYNES

INTRODUCTION

In the west central part of Riley county, twenty miles northwest of Manhattan and one mile east of Bala, on the Chicago, Rock Island & Pacific railroad, about 500 feet north of the track, is a small outcrop of a dark green rock which is of great geologic interest, and yet appears to have escaped notice in print until the present time.

Credit for the discovery belongs to Mr. T. S. Harrison, of Denver, who examined the outcrop and recognized its igneous character on a visit in 1919. He reported it to the writers who have made a study of the rock in the field and a petrographic investigation from thin sections in the laboratory. Mr. Wallace Pratt also visited this locality and has provided a petrographic report, which is quoted in this paper.

HISTORY

According to the information obtained at Bala from an old settler, it appears that in 1871 three men from Pittsburg, Pa., sunk a shaft near the western margin of the outcrop east of Bala and shipped a considerable amount of the dark colored rock back to Pittsburg. They thought they had found copper ore, but they never returned to Bala. All signs of the old shaft have entirely disappeared.

MANNER OF OCCURRENCE

The rock under consideration forms a low, dome-like, grass-covered mound, with a maximum elevation of about thirty feet above a small creek which swings about its north and west sides. The mound blends to the southeast into a gentle ridge which flattens out into rolling fields.

The total area of the mound is not more than one acre, and the weathered fragments of the dark green rock were not found more

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Raymond C. Moore and Winthrop P. Haynes, Lawrence, Kansas.

than 100 feet beyond the limits of the symmetrical mound. There are two good sized outcrops, both located near the base of the hill, one on the west side and the other on the north. They are respectively about 9 feet high by 5 feet wide, and 6 feet high by 10 feet wide. They reveal a massive uniformly-colored rock, cut by a well defined system of joints which dip about 60° N. The rock is traversed in various directions by veins of calcite, which are rather prominent on account of their contrast in color to the mass of the rock. Distinct but somewhat irregular flow-banding, with alternating coarse and fine zones, appears on part of the western outcrop.

The nearest outcrop of typical Permian sedimentary rocks of this region is an exposure of limestone and shale near the railroad about 500 feet south of the rounded mound. In a long cut just west of this exposure there are a few very small folds, but no other noteworthy feature. The record of a well located about 200 feet north of the northern outcrop on the Davis farm shows shale to about 90 feet, and then limestone to 100 feet, where dark green rock similar to that exposed in the hill was encountered. The well was deepened from 88 to 118 feet about a year ago and now terminates in the dark green rock. Mr. Pratt obtained a sample of the limestone from the well and reports that it shows a highly vesicular character, but is very hard and partly dolomitized, and there is a suggestion of alteration by solution. A thin section shows that it is a fine grained crystallic limestone, with about 96 per cent calcite and impurities of small particles of quartz, pyrite and bituminous markings

PETROGRAPHY

Careful examination of the rock shows a distinct crystalline groundmass with numerous inclusions of shale in all stages of alteration. The rock is an igneous breccia.

MACROSCOPIC CHARACTER

The color of the rock ranges from a dark green to brownish-black, with a mottling of lighter shades, due to the inclusions and also to veins and replacements of calcite. The weathered surface of the ledges is in places porous with a suggestion of gas cavities, but it is probably due to solution accompanying weathering.

Groundmass. The groundmass, which constitutes from two-thirds to three-fourths of the rock is very dense and finely

crystalline, as seen in the freshly broken surfaces of the least weathered parts of the outcrop. It has a deep olive-green color. In places coarser crystalline zones, which are probably due to flowage, are visible.

Inclusions. Angular to subangular and rounded inclusions of a rather light olive-green color are present, even in portions of the outcrop farthest from the contacts, but they are much less abundant than in the rock near the margins, and also they show all degrees of rounding and apparent absorption about their borders and are baked to a hard porcelainite. The marginal inclusions range in size from very small fragments to pieces 2.5 inches in diameter. In many instances they show well-marked stratification banding and shaly fracture indurated by the igneous contact.

Minerals. The crystalline groundmass is generally too fine grained and too much altered by weathering to be studied to advantage with a hand lens. It is possible, however, to identify the following materials—Primary: Chromite (abundant), biotite (in a few specimens); Secondary: Calcite, serpentine, chlorite, kaolin, limonite.

Specific gravity tests on small samples gave an average of 2.48 for this composite rock.

MICROSCOPIC CHARACTER

The general features shown in three thin sections are a distinct porphyritic structure with finely crystalline groundmass and phenocrysts, which are in part true phenocryts and in part the smaller inclusions. Inasmuch as the groundmass contains the only primary minerals it will be considered first.

Groundmass. Primary minerals: Chromite, black and opaque, in irregular grains, usually showing a limonitic stain about the borders, and in a number of cases surrounded by kaolin stained reddish brown by the weathering of the chromite, 5 to 10 per cent of groundmass. No biotite was recognized in the sections.

Secondary minerals The groundmass is chiefly composed of serpentine and calcite. The serpentine is in pale greenish-yellow masses and stringers, and the calcite in irregular grains. These two secondary minerals break up the outline of the original minerals and produce a heterogeneous mass which is very difficult to identify. The striking features of the groundmass are the phenocrysts and the inclusions.

Phenocrysts. (a) Some of the phenocrysts show fairly sharp angular outlines which are recognizable as original pyroxene crystals now changed to pale yellowish green serpentine, green chlorite and calcite; (b) some are rounded grains, which show irregular cracks and coloration varying from pale yellowish-green to darker green, these are regarded as altered olivine crystals; (c) a considerable portion of the apparent phenocrysts vary from irregularly angular to rounded forms, are of extremely variable sizes, generally larger than (a) and (b), and show zonal bands about the margins. In plane polarized light the colors are pale yellowish-green with a border zone of darker tone which is distinctly granular. Under crossed nicols these masses are seen to be composed of an aggregate of very fine grains, chiefly quartz and kaolin with some feldspar. These pseudo-phenocrysts therefore are regarded as inclusions of shale in a more or less altered condition.

The writers are indebted to Mr. Wallace Pratt for the following report of two thin sections of this rock, which were studied by Mr. W. Harold Tomlinson, of Swarthmore, Pa.: "Samples 2 and 3 are metamorphosed basic igneous rocks, probably dikes. Section of Sample 2 shows serpentine and calcite to be the principal minerals, apatite and a black (brown by transmitted light when very thin), metallic mineral of the isometric system, probably chromite, are accessory. The rock is thickly porphyritic. The phenocrysts which form about half the rock are rounded and consist of serpentine and calcite replacing olivine. A few have the form of augite, but as the angles have been rounded in alteration it is impossible to say what proportion. The apatite occurs rather thickly in small rounded crystal grains. There is a little chlorite with the serpentine. Sample 3 is a very similar rock, but does not have the apatite. Some of the phenocrysts in this sample are altered biotite, some probably augite, but the great majority altered olivine. There is relatively more calcite and less serpentine. Brucite was found with the serpentine in an altered phenocryst of olivine. Metamorphism by carbonation and hydration is extreme in both samples. I would classify both 2 and 3 as kimberlite or porphyritic peridotite."

Mr. Tomlinson's approximate analyses of these samples are as follows:

SAMPLE No. 2:

Minerals Present:	*Original Minerals:*
Serpentine, 75%	Olivine,
Calcite, 15%,	Augite,
Chlorite,	Biotite,
Chromite,	Chromite,
Apatite.	Apatite.

SAMPLE No. 3:

Minerals present:	*Original Minerals:*
Serpentine, 60%,	Olivine,
Calcite, 30%,	Augite,
Chlorite,	
Chromite	Chromite,
Brucite,	
Magnetite.	Magnetite.

It will be noted that Mr. Tomlinson makes no mention of the type (c) pseudo phenocrysts or shale inclusions. It is possible that his samples may not have contained them, though this seems unlikely in view of their widespread occurrence through the igneous rock in all parts.

ORIGIN

Consideration of the petrographic and general geologic characters of this rock, which is so strikingly unlike the common sedimentary rocks of the Kansas plains, leads to the conclusion that the mass is a rather small volcanic neck, or pipe, which is either inclined to the north, or widens outward with depth. The angular or subangular fragments of shale which show various degrees of induration and metamorphism are evidently pieces of the adjacent country rock, upper Permian shales. The lack of evidence of pronounced metamorphism or disturbance in the surrounding sediments indicates that the intrusion was not violent and it is probably a very local, perhaps an isolated remnant, of volcanic activity in the region. Beyond the obvious fact that the rock is younger than early Upper Permian, little concerning the age of the intrusion may be vouchsafed.

Its possible significance to the prospector for petroleum is uncertain. It is not likely that there is any relation similar to the occurrence of oil adjacent to basic intrusions in the Mexican fields.

A CRITICISM OF THE RULE OF TEN DOLLARS INCREASE IN BARREL-DAY PRICES, WITH EVERY ONE CENT INCREASE IN THE PRICE OF CRUDE OIL.

JOSEPH L. TWEEDY

The old rule of $10.00 increase in barrel-day prices with one cent increase in price of crude oil is dangerous and misleading, because it is dependent primarily on the decline rate of a well, and this, of course, varies with the pool and the age of the well.

The purpose of this paper is to show modifications made necessary by the difference in decline rate, and will also show under what condition the ration of $10.00 to one cent can be applied.

The data from which the conclusions are drawn are taken from the Appalachian field, since the rule has been used more extensively in that field than in any other, and also since this method of valuing property is based on settled production, the wells in this field could be considered as nearly settled as any in the country.

In a paper entitled "Variations in Decline Curves of Various Oil Pools," presented by Roswell H. Johnson, at the February meeting of the American Institute of Mining Engineers, there is shown for the various oil pools in the country, the amount of oil produced by wells during a decline from 3,000 barrels to 2,000 barrels per year, and during a decline from 500 barrels to 100 barrels per year. In the Appalachian field the production of wells during a decline from 500 barrels to 100 barrels per year, varies from a minimum of 450 barrels to a maximum of 3,150 barrels with a median of 1,700 barrels, and a mean of 1,655 barrels. If we apply a barrel-day price to these different amounts produced, we find that the barrel-day price which should be paid, varies according to the amount of oil the well will produce during this decline. The ratio between the increase in barrel-day prices and increase in price of crude oil, instead of being a flat $10.00 to one cent ratio, varies from $4.10 to one cent for the 450 barrel well to $28.64 to one cent for the 3,150 barrel well. The following table shows approximately

Joseph L. Tweedy, Pittsburg, Pa.

what barrel-day prices should apply with different amounts of oil produced, and with different operating costs. But the different costs have no effect on the ratios, as they are constant. In giving these approximate values, there must be taken into consideration the fact that compound discount, variation in cost and the change in the price of oil, arising from the length of time involved, has been ignored, as the data from which these figures are taken did not give the length of time required for these various declines. However, the great range which has been shown could not be reduced to any great extent relatively by such consideration.

In arriving at these values the following formula was used:

N = Bbl. day price unit.
$D.\ P_1$ = Daily production at rate of 500 bbls. per year.
$D.\ P_2$ = Daily production at rate of 100 bbls. per year.
P = Production during decline.

To find the value of N:

$$D P_1 \times N = (D P_2 \times N) + (P \times \text{price of oil}) - (P \times \text{bbl. cost}).$$

TABLE I

Table showing difference in barrel-day prices and differences in ratio between increases in barrel-day prices and increases in prices of crude oil, with wells producing different amounts during a decline from 500 bbls. to 100 bbls. per year:

Production	Price of Oil	Value expressed in barrel-day prices with various operating costs.				Ratio
		.10 per bbl.	.20 per bbl.	.30 per bbl.	.50 per bbl.	
450 bbls.	$1.00	368	327	286	204	$4.10 to .01
	2.00	777	735	695	613	
	3.00	1,186	1,145	1,109	1,023	
	4.00	1,595	1,554	1,514	1,613	
	5.00	2,005	1,963	1,922	1,840	
1,655 bbls.	$1.00	1,355	1,203	1,053	752	$15.02 to .01
	2.00	2,858	2,708	2,558	2,254	
	3.00	4,364	4,213	4,062	3,761	
	4.00	5,868	5,717	5,567	5,265	
	5.00	7,372	7,222	7,071	6,770	
1,700 bbls.	$1.00	1,391	1,236	1,081	772	$15.45 to .01
	2.00	2,935	2,783	2,627	2,318	
	3.00	4,483	4,327	4,172	3,863	
	4.00	6,027	5,873	5,718	5,410	
	5.00	7,573	7,418	7,263	6,954	
3,150 bbls.	$1.00	2,577	2,291	2,004	1,431	$28.64 to .01
	2.00	5,441	5,155	4,868	4,295	
	3.00	8,305	8,018	7,731	7,160	
	4.00	11,168	10,882	10,595	10,022	
	5.00	14,032	13,745	13,459	12,886	

In the Appalachain field, the production of wells during a decline from 3,000 barrels to 2,000 barrels per year varies from a minimum of 450 barrels to a maximum of 2,750 barrels with a median of 1,225 barrels and a mean of 1,489 barrels. In applying barrel-day prices, we find that the barrel-day price which should apply varies with the amount of oil produced, and that the ratio between increase in barrel-day prices and increase in price of oil varies from $163 to one cent for the 450 barrel well, to $9.92 to one cent for the 2,750 barrel well. Table II shows the different barrel-day prices applicable, and the various ratios. The method previously used was employed in finding these values.

TABLE II

Table showing differences in barrel-day prices and differences in ratio between increases in barrel-day prices and increases in prices of crude oil, with wells producing different amounts during a decline from 3,000 bbls. to 1,000 bbls. per year:

Production	Price of Oil	Value expressed in barrel-day prices with various operating costs.				Ratio
		.10 per bbl.	.20 per bbl.	.30 per bbl.	.50 per bbl.	
450 bbls.	$1.00	146	130	114	81	$1.63 to .01
	2.00	309	292	276	244	
	3.00	471	455	439	406	
	4.00	634	617	601	569	
	5.00	796	780	764	731	
1,225 bbls.	$1.00	398	354	310	221	$4.42 to .01
	2.00	839	796	752	664	
	3.00	1,282	1,238	1,194	1,105	
	4.00	1,725	1,679	1,636	1,545	
	5.00	2,167	2,122	2,079	1,989	
1,489 bbls.	$1.00	484	430	376	269	$5.37 to .01
	2.00	1,021	968	914	806	
	3.00	1,559	1,505	1,451	1,344	
	4.00	2,096	2,043	1,989	1,882	
	5.00	2,634	2,580	2,526	2,419	
2,750 bbls.	$1.00	893	794	695	497	$9.92 to .01
	2.00	1,886	1,787	1,688	1,489	
	3.00	2,879	2,780	2,677	2,482	
	4.00	3,871	3,772	3,673	3,473	
	5.00	4,864	4,765	4,664	4,467	

Table III shows approximately how much oil a well should produce during a decline from 500 barrels to 100 barrels per year and during a decline from 3,000 barrels to 2,000 barrels per year in

order to permit the application of the $10.00 to one cent rule. In arriving at the amounts of production the following formula was used:

$D\,P_1$ = Daily production at rate of 500 bbls. and 3,000 bbls.
$D\,P_2$ = Daily production at rate of 100 bbls. and 2,000 bbls.
P = Production during decline.

To find the value of P.:

$$D\,P_1 \times \$1{,}000 = D\,P_2 \times \$1{,}000 + (\tfrac{7}{8}P \times \$1.00) - (P \times \text{bbl. cost}).$$
$$D\,P_2 \times \$2{,}000 = D\,P_2 \times \$2{,}000 + (\tfrac{7}{8}P \times \$2.00) - (P \times \text{bbl. cost}).$$

TABLE III

Table showing production necessary to maintain $10.00 to .01 ration between increase in bbl.-day prices and increase in bbl.-day prices and increase in price of crude oil with different operating costs and different periods of decline:

Production	Price of Oil	Value expressed in barrel-day prices with various operating costs.				Ratio
		.10 per bbl.	.20 per bbl.	.30 per bbl.	.50 per bbl.	
During decline of wells from 500 to 100 bbls. per year.	$1.00	1,423	1,634	1,918	2,941	
	2.00	1,337	1,423	1,521	1,765	
	3.00	1,310	1,363	1,423	1,557	
	4.00	1,298	1,337	1,379	1,471	
	5.00	1,290	1,321	1,353	1,423	
During decline of wells from 3,000 to 2,000 bbls per year.	$1.00	3,587	4,119	4,835	7,413	
	2.00	3,370	3,587	3,834	4,480	
	3.00	3,303	3,439	3,587	3,925	
	4.00	3,271	3,370	3,475	3,707	
	5.00	3,252	3,329	3,411	3,587	

It will be noticed that as the price of crude oil advances, there is a decrease in the amount of production necessary to maintain the $10.00 to one cent ratio, but the curve of these decreases in production does not, as at first might be supposed, resemble in any way the decline curves of any oil wells. From data taken from Carl H. Beal's tables in Bureau of Mines, Bulletin 177, are here shown on logarithmic paper decline curves of several oil wells and also curves made by the decreases in production necessary to maintain $10.00 to one cent ratio, and it can be readily seen that the two types of curves are in no way similar.

While the figures in this paper only attempt to give the trend and approximate values of wells producing certain amount of oil during different periods of decline, it would seem that where the data are

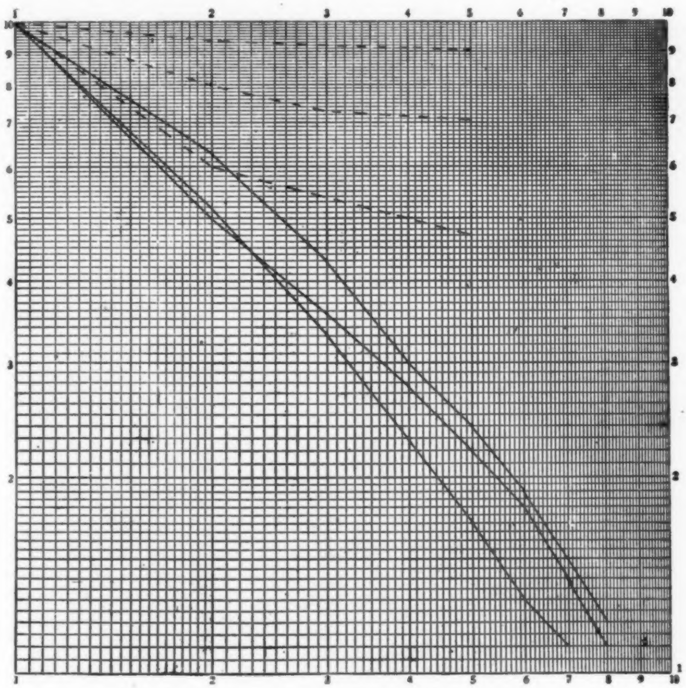

FIGURE 1. A comparison between two types of curves.

The solid lines represent typical decline curves of wells as taken from Bulletin 177, U. S. Bureau of Mines.

The broken lines represent the necessary decline in production of wells in order to maintain the $10.00 to .01 ratio in barrel-day prices.

obtainable some such table of ratios for wells of one pool and age would be valuable both as a guide in purchasing new properties, and also as a means of easily reappraising old properties as the price of crude advances.

CONCLUSIONS

The ratio of $10.00 increase in barrel-day price to one cent increase in price of crude oil does not hold for all properties owing to difference in rate of decline.

The ratio is not constant throughout life of any one property, owing to change in decline curve.

The ratio is not constant for all properties, but varies with pcol and age of the well.

The barrel-day price unit is not constant throughout life of any one property, but varies as decline curve changes, as well as with increase in operating cost and increase in price of crude oil.

NOTES ON THE OIL SHALES OF SOUTHWESTERN WYOMING

E. F. Schramm

Most of the oil producing shales of Wyoming are confined to the Green River formation. In the southwestern part of Wyoming this formation has a maximum thickness of about 1,800 feet. A section measured by R. H. Hawn, and the writer, north of Kanda (east of the Green River station), has a total thickness of 1,785 feet.

The formation is composed predominately of light colored in part calcareous shales, interstratified with brown to black bituminous shale, gray sandstones and shaly limestones. Near the base as exposed east of the Meridan Anticline, in Uinta county, the light colored shales and sandstones are interstratified with red shales. The middle and upper portions of the formation consist of gray argillaceous shales and sandstones interstratified with bluish gray to brown and black oil shales. The rich oil shales, which on fresh fracture are dark brown to black, weather at the surface to white or bluish gray. These rich shales are well exposed in escarpments along drainage lines in T. 17 N., R.106 W., and 18 N., R.107W. The black rich beds of thin hard shale are more resistant to erosion, and when interstratified with lean or non-oil bearing strata, weather to projecting benches and shelf-like forms. This is illustrated in Figure 1. Some of the hard rich shale beds, which produce 50 to 60 or more gallons of oil per ton of shale, have a lustre similar to gilsonite or the harder varieties of asphalt. Some pieces resemble cannel coal. If a piece of the shale is abraded with a pick, scratched with a knife, or rubbed against another piece of shale or rock, it gives the distinctive odor of petroleum. This odor is very pronounced to one mining the shale in a narrow open cut.

The rich shale will burn in a stove and is used for fuel by some ranchmen in a number of localities in southwestern Wyoming. A shale which produced 90 gallons of oil per ton was used as fuel for

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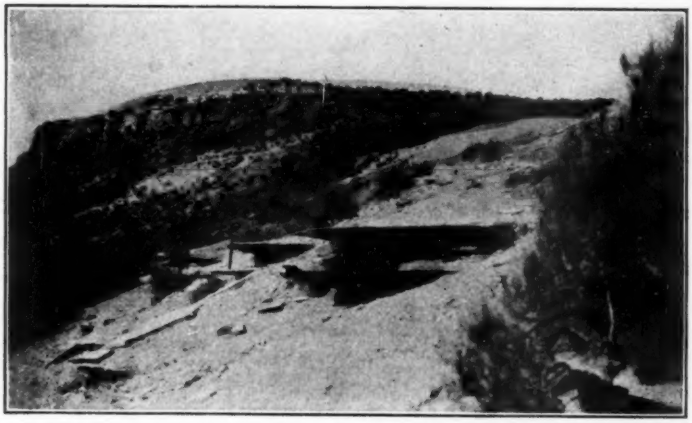


FIGURE 1. Shelf weathering of thin layers of rich oil shale, Section 4, Township 20 North, Range 118 East.

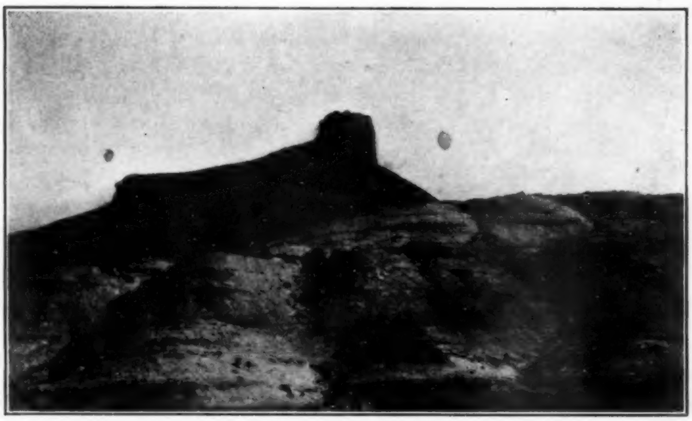


FIGURE 2. View of the Green river formation. The massive member at the top is the Tower or Channel sandstone. Township 18 North, Range 107 West.

three weeks in one of the camps of the writer. The hard compact, rich black shale, which outcrops as a projecting shelf over lean shale, contains so much oil that it is only slightly affected by weathering. There was a variation of from two to five gallons of oil per ton of shale in two samples collected from a rich hard shale, two samples being taken at the outcrop and the other two taken at the face of an open cut ten feet back from the outcrop.

The so-called paper shales are very thin, flexible and light brown in color. They contain numerous joint planes and are much affected by weathering. Adits which have been driven on the dip of some paper shale beds show the shale weathered a distance of ten to twenty feet from the surface. On the contrary one entry opened on a paper shale bed in T. 18 N, R. 107 W., about two miles northeast of Green River station, changed to a hard compact shale within a few feet from the mouth of the entry. At the face of the entry, 30 feet in on the bed, the shale was very hard and compact. Some of the surface paper shales give on distillation only a small amount of oil, while unweathered samples on the same bed frequently produce twice as much oil as the weathered samples.

Paper shales appear to be due entirely to weathering, the shale parting readily along thin bedding planes. Such shales contain considerable organic matter which is only partially decomposed.

The lithologic characteristics of the oil shale beds vary widely in different localities and also along the dip and strike of the same bed.

A section 50 to 100 feet thick may be made up entirely of oil bearing shale, but composed of a number of varieties, which may include hard, rich black shale, thin paper or plate shale, calcareous, argillaceous or arenaceous shales. Such a section may also show a variation in oil content in the different layers from 1 to 90 gallons per ton.

The thickest and richest beds of oil shale discovered by the writer in southwestern Wyoming are in Ts. 16, 17 and 18 N., Rs. 106 and 107 W. One section in the Green River formations measured in Sec. 14, T. 18 N., R. 106 W, containing 36 oil shale members varying in thickness from 6 inches to 68 feet and in oil content from lean to 65 gallons per ton of shale. The base of the section is located in the bed of Bitter Creek near the Kanda Pumping Station.

FIGURE 3. Rich oil shale twenty feet thick. Section 14, Township 18 North, Range 106 West.

FIGURE 4. Interstratified beds of rich and lean shale, overlain by the Tower or Channel sandstone. Township 18 North, Range 107 West.

Section of Green River formation on Bitter Creek:

	Feet	*Inches*
Covered Slope	10	
Sandstone, buff to brown, fine grained, shaly	23	
Shale, gray to buff, limy, sandy	68	
Sandstone, gray to buff, fine grained, shaly	5	
Shale, brown to buff, limy, sandy	38	
Sandstone, buff, fine grained, soft	4	
Shale, grayish buff interbedded with thin sandstones	7	
Shale, gray, limy	1	8
Sandstone, gray to buff weathers brown, interbedded with gray shales, cross bedded, variable on strike of beds	195	
Shale, greenish gray	24	
Shale, brown, paper shale	1	
Shale, brownish gray to cream, fissile	9	
Shale, gray, sandy	5	
Sandstone, gray, limy, compact		8
Sandstone, gray to buff, very shaly, interbedded with gray shales	168	
Sandstone, gray, interbedded with gray shales	5	
Shale, grayish brown, paper shale	13	
Sandstone, brownish gray, shaly	2	
Shale, grayish brown, rotten paper shale		8
Shale, *oil bearing*, very black, hard	2	
Shale, *oil bearing*, dark brown to black	3	
Shale, *oil bearing*, lean, gray to brown, limy, paper shale	3	
Shale, *oil bearing*, dark brown to black, paper shale. Sample number 55A taken from this member gave on analysis 65 gallons of oil per ton of shale	15	
Sandstone, gray to buff, shaly, soft	1	6
Shale, *oil bearing*, dark brown to black, paper shale	10	6
Sandstone gray, fine, grained		6
Shale, *oil bearing*, brown, thin bedded, fissile	7	
Shale, gray, thin bedded, limy	13	
Shale, *oil bearing*, lean, brown to dark brown, thin bedded	3	
Shale, gray, sandy	3	
Shale, pink to brown, dusty	3	
Shale, gray, limy, sandy	4	
Shale, *oil bearing*, brown to black, fissile, contains a few very thin sandstones. Sample number 53 taken from this member gave on analysis 17 gallons of oil per ton of shale	25	
Shale, gray, contains a few thin sandstones	35	
Sandstone, gray to white, shaly	3	
Shale, gray, contains a few thin shaly sandstones	30	6
Sandstone, white, thin bedded, weathers brown	4	
Shale, black to gray, sandy and limy, lower two inches lean oil shale	3	
Sandstone, gray, shaly, fine grained	2	
Shale, *oil bearing*, brown to black, contains some lime	2	
Shale, brown to black, weathers gray	13	6
Shale, greenish gray	1	6
Sandstone, greenish gray, contains finely disseminated mica	2	
Shale, gray, slightly sandy	8	
Shale, *oil bearing*, brown to black, paper shale	1	8
Shale, gray, sandy, contains a few thin sandstones	10	
Shale, *oil bearing*, lean, light brown to black	1	10
Shale, gray, contains a few thin bedded shaly sandstones	6	
Sandstone, gray, very limy, fine grained, contains finely disseminated mica	3	
Shale, gray, interbedded with thin sandstones	18	
Sandstone, gray, fine grained	2	
Shale, gray, sandy, interbedded with thin sandstones	9	
Shale, *oil bearing*, lean, brown to black	1	6

	Feet	Inches
Shale, gray, sandy	22	
Sandstone, white, thin bedded, shaly	2	
Shale, gray	4	
Shale, *oil bearing*, lean, brown, fissile		8
Shale, gray	1	6
Shale, gray to white, interbedded with thin sandstones	10	
Shale, gray, sandy	13	
Shale, *oil bearing*, brown to black, thin bedded	2	
Shale, gray, sandy		8
Sandstone, white, fine grained	2	
Shale, gray	3	
Shale, *oil bearing*, brown to black, fissile		6
Shale, gray, slightly sandy	2	
Shale, *oil bearing*, black to brown	1	
Shale, gray, slightly sandy	2	6
Sandstone, white, fine grained, thin bedded	2	
Shale, gray, sandy, thin bedded	1	
Shale, *oil bearing*, brown to black, paper shale	1	
Shale, gray, sandy		6
Shale, greenish gray	8	
Sandstone, white, fine grained, sugary		8
Shale, gray	5	
Limestone, gray, sandy	6	
Shale, *oil bearing*, dark brown to black paper shale. Sample 56 taken from this member gave on analysis 19 gallons of oil per ton of shale	2	
Shale, olive	3	
Shale, gray	3	
Shale, *oil bearing* lean, dark brown		6
Shale, brown, limy		6
Sandstone, grayish white, thin bedded, ripple marked	6	
Shale, dark gray, slightly sandy	3	
Sandstone, white, ripple marked	2	
Shale, olive gray	11	
Sandstone, gray to white, thin bedded, fine grained	1	6
Shale, greenish gray	14	
Sandstone, thin bedded, gray	1	
Shale, gray, sandy	13	
Shale, brown, fissile, fossiliferous	1	
Sandstone, gray, thin bedded, ripple marked, interbedded with gray shale	5	2
Shale, gray, sandy, soft	13	
Limestone, dark brown, platy, interbedded with six inches of brown shale slightly oil bearing	1	8
Shale, grayish brown, interbedded with a few thin sandstones, shaly and thin bedded	35	
Limestone, gray, thin bedded, sandy, interstratified with gray shales	4	6
Shale, *oil bearing*, lean, brown, sandy		6
Shale, *oil bearing*, dark brown		6
Shale, gray, sandy	2	
Limestone, gray shaly		6
Shale, gray, sandy		6
Limestone, gray, thin bedded, shaly	1	6
Shale, greenish gray, sandy	9	6
Limestone, gray, shaly, interbedded with sandy shale	2	
Shale, dark gray	2	8
Shale, gray, sandy, dark greenish gray at top	10	
Shale, dark brown, fissile	1	
Shale, gray, interstratified with thin, sandy limestones	20	
Shale, gray, sandy	8	
Sandstone, gray, thin bedded, interstratified with gray shale	2	
Shale, gray, sandy	5	
Sandstone, greenish gray, weathers brown, shaly, thin bedded	9	
Shale, gray, contains a few thin sandstones near center	13	
Sandstone, brown, shaly	3	
Shale, greenish gray	4	
Sandstone, greenish gray, with brown spots	8	
Sandstone, gray, shaly	12	
Shale, greenish gray	10	
Sandstone, gray, shaly	13	
Shale, gray, sandy, limy, thin bedded	5	
Sandstone, gray, fine grained, thin bedded	1	6
Shale, greenish gray, sandy	13	
Limestone, gray, sandy	1	6
Shale, greenish gray, soft, limy	8	

	Feet	Inches
Shale, gray, limy	4	
Shale, *oil bearing*, brown, paper shale. Sample 55 from this member gave on analysis 38 gallons of oil per ton of shale	3	
Shale, brown, compact, weathers light gray	8	
Shale, brown, weathers grayish white	5	
Shale, *oil bearing*, brown, paper shale	2	6
Sandstone, gray, shaly		6
Shale, gray, contains clay concretions	1	4
Shale, *oil bearing*, brown, paper shale. Sample 53 from this member gave on analysis 17 gallons of oil per ton of shale	2	
Shale, brown, hard	1	
Shale, *oil bearing*, brown paper shale. Sample 49 from this member gave on analysis 15 gallons of oil per ton of shale	6	6
Shale, light brown, fissile	4	
Shale, gray, limy, contains beds of brown shale bearing a small amount of oil	15	
Sandstone, brown, iron oxide disseminated throughout	6	
Shale, gray, sandy	9	
Sandstone, greenish gray, specked with iron oxide stains	1	6
Shale dark, gray, soft	15	
Sandstone, gray to brown, shaly and limy	1	6
Shale, gray, sandy		11
Shale, *oil bearing*, lean, dark brown at base, light at top, weathers gray	19	8
Sandstone, gray, slabby	1	6
Shale, gray, sandy	10	
Shale, gray, sandy, contains thin sandstones	18	
Shale, gray, sandy and limy	1	6
Shale, greenish gray, sandy	14	
Shale, gray, sandy and limy	1	
Shale, gray, sandy	13	
Sandstone, gray, shaly, limy, fine grained	3	
Shale, gray, sandy	4	
Shale, dark, carbonaceous	22	
Shale, gray, fissile, sandy, limy	8	
Shale, greenish gray, limy	35	
Shale, dark, carbonaceous	4	
Shale, gray, sandy	12	
Sandstone, brown, hard, fine grained, interbedded with gray shale	4	
Shale, gray, sandy, weathers buff	25	8
Shale, *oil bearing*, lean, gray covered in part by hill wash	20	
Shale, gray, sandy, weathers buff	10	
Shale, *oil bearing*, lean, dark, carbonaceous	45	
Shale, *oil bearing*, gray to brown, contains a few thin sandstones. Sample 50 from this member gave on analysis 17 gallons of oil per ton of shale	12	
Shale, *oil bearing*, black, hard. Sample 51 and 52 from this member gave on analysis 19 gallons each of oil per ton of shale	8	
Shale, *oil bearing*, dark brown and limy at base, changes to gray at top, contains fossil remains of fish, thin sandstones and limestones	68	
Shale, *oil bearing*, dark, carbonaceous	10	
Shale, *oil bearing*, dark brown, paper shale		6
Sandstone, gray, fine grained		9
Shale, *oil bearing*, dark brown		2
Shale, *oil bearing*, gray, thin bedded	1	
Sandstone, shaly, gray to buff		3
Shale, *oil bearing*, gray to brown	6	
TOTAL THICKNESS	1,784 feet	11 in.

The oil shales of the Green River formation west of Cumberland, in Ts. 18 and 19 N., Rs. 118 and 119 W., are lean and of little economic value. Samples collected from a thin bed north of Elk Mountain in Sec. 17, T. 20 N., R. 118 W. on distillation gave 53 gallons of oil per ton of shale.

FIGURE 5. Line of unconformity in Green river formation between Tower sandstone and underlying shales. Section 9, Township 18 North, Range 107 West.

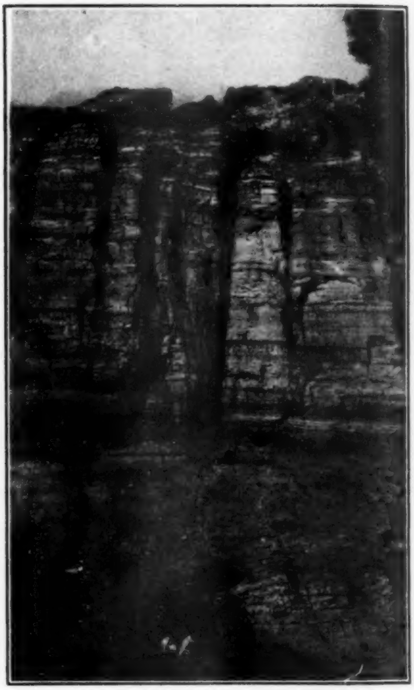


FIGURE 6. Thick beds of oil shale, capped by Tower or Channel sandstone. Section 9, Township 18 North, Range 107 East.

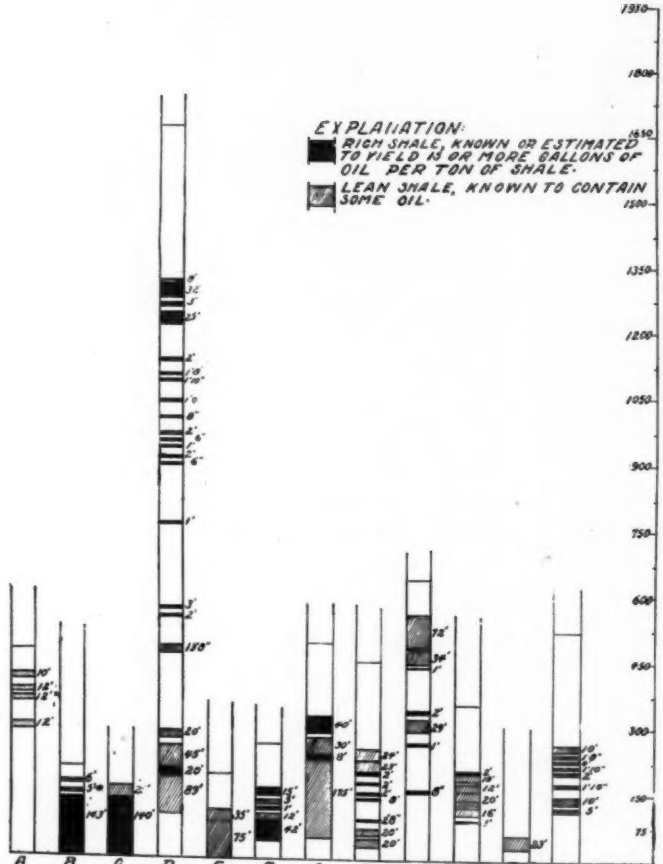
The following table gives the results of distillations of oil shale samples collected by the writer from various localities in southwestern Wyoming. The apparatus used in making the field test was practically identical with that used by the United States Geological Survey in making similar field tests. This is fully described in the Survey Bulletin 641-F. The shale was heated until gas ceased to be driven off, which was from three to five hours. Samples 107 to 131, inclusive, were collected and analyzed by Dean E. Winchester of the United States Geological Survey.

Results of distillation of samples of oil shale collected in Uinta, Lincoln and Sweetwater counties, Wyoming:

No.	Location			Thickness	Wt. of Shale, Oz.	Ash Oz. approx	Oil per ton	NH_4 SO_4 Lbs.	Dry base, Gals.	Specific Gravity
	Sec.	T-N	R-W							
A	31	19	118	......	4	......	21	5.8	23	0.861
B	31	19	118	......	8	......	1	......	11.2	......
C	31	19	118	......	8	......	6	0.3	7.7	......
1	29	19	118	1′ 2″	8	7.5	1	......	1.2	......
2	29	19	118	2′ 11″	8	7.5	1.	2.9	3.3	......
3	29	19	118	1′ 10″	8	7.5	15	......	.6	......
4	29	19	118	2′ 6″	8	7.5	1.	......	1.2	......
5	29	19	118	4″	8	7.5	5	2.6	5.9	0.859
6	29	19	118	4′ 2″	8	7.5	2	......	2.0	......
7	29	19	118	7′	8	7.5	2	......	2.0	......
8	Elk	Moun	tain	......	8	6.	23	0.5	24.0	0.859
8A	Elk	Moun	tain	......	8	......	39	......	40.0	......
9	29	19	118	......	8	7.	16	2.6	17.5	0.860
10	31	19	118	1′ 2″	8	7.5	1	......	0.0	......
11	31	19	118	2′ 1″	8	......	......	......	......	......
12	31	19	118	2′ 1″	16	15.5	.5	......	.5	......
13	31	19	118	......	8	7.5	.5	......	.5	......
14	18	19	118	......	8	7.5	.5	......	.5	......
15	18	19	118	......	16	15.	3	1	4	......
16	32	19	118	......	8	7.5	1	......	1.	......
17	32	19	118	1′ 6″	8	7.5	3	......	3.	......
18	32	19	118	2′	8	7.5	1	......	1.0	......
19	18	19	118	......	8	7.5	6	......	......	......
19A	18	19	118	4″	4	3.5	19	3.3	20.0	......
20	18	19	118	......	8	7.5	5	1.2	5	......
21	18	19	118	......	8	7.5	.5	......	.5	......
22	18	19	118	12′	8	7.5	2	2.	2.	......
23	36	19	119	1′ 2″	8	7.5	5	3.49	5.7	0.896
24	17	18	119	1′	8	7.5	8	1.20	.9	0.876
25	18	19	118	1′ 1″	8	7.5	2	......	2	......
26	18	19	118	2′ 9″	8	7.5	1	......	1.0	......
27	18	19	118	......	8	7.5	6	3.1	6.5	......
28	18	19	118	......	8	7.5	2	......	2.0	......
29	18	20	118	12′	4	2.5	53	15.	61.	0.871
30	18	20	118	......	8	7.5	18	2.55	18.	......

No.	Location			Thickness	Wt. of Shale, Oz.	Ash Oz. approx	Oil per ton	NH_4 SO_4 Lbs.	Dry base, Gals.	Specific Gravity
	Sec.	T-N	R-W							
31	18	20	118	...	4	3.5	19	2.48	19.	0.858
31A	18	20	118	...	4	3.	25	1.85	25	0.854
32	18	20	118	10′	4	3.5	23	2.01	23	0.846
33	18	20	118	20′	8	7.5	3	0.76	3	...
34	18	20	118	...	4	3.5	11	...	11	0.904
35	17	19	118	1′	8	3.5	2	2.01	2.05	0.888
36	17	19	118	3′ 6″	8	7.5	5	0.91	5	0.887
37	17	19	118	...	8	7.5	9	2.99	11	0.867
38	17	19	118	...	8	7.5	0	...	0	...
39	17	19	118	...	8	7.5	0	...	0	...
40	22	18	107	6″	4	3.	53	...	55	...
41	22	18	107	1′ 6″	4	3.5	29	...	32	...
42	22	18	107	8″	4	3.5	44	...	45	...
43	22	18	107	22′	8	7.5	5	...	5	...
44	22	16	108	...	4	...	15	...	16	...
45	22	16	108	...	8	7.5	2	...	2	...
46	20	17	115	...	4	3.5	6	...	7.5	...
47	20	17	115	...	8	7.5	1	...	3	...
48	20	17	115	...	8	7.5	.5	...	.6	...
49	14	18	106	...	4	3.5	15	...	17	...
50	14	18	106	...	4	3.5	17	...	18	...
51	14	18	106	...	4	3.5	19	...	18	...
52	14	18	106	...	4	3.5	19	...	21	...
53	14	18	106	...	4	3.5	17	...	18	...
54	14	18	106	...	4	3.5	19	...	22	...
55	14	18	106	...	4	3.5	38	...	44	...
55A	14	18	106	...	4	3	65	...	22	...
56	14	18	106	...	4	3.5	19	...	20	...
57	14	18	106	...	8	7.5	4	...	5	...
58	6	17	106	90′	4	3.5	34	...	35	...
59	6	17	106	...	8	7.5	0	...	0	...
60	5	14	108	1′	4	3.5	38	...	39	...
61	5	14	108	2′	4	3	46	...	47	...
62	5	14	108	1′	4	3	55	...	57	...
63	15	18	107	...	4	3.5	32	...	35	...
63A	15	18	107	...	4	3.5	29	...	32	...
63B	15	18	107	...	4	3.5	31	...	23	...
64	15	18	107	...	4	2.5	88	...	92	...
65	28	18	107	6″	4	3.5	17	...	18	...
66	28	18	107	1′ 6″	4	3.5	15	...	16	...
67	28	18	107	8″	4	3	53	...	57	...
68	28	18	107	2′ 4″	4	3.5	34	...	37	...
69	9	17	106	20′	8	7.5	4	...	5	...
70	9	17	106	30′	4	3.5	17	...	18	...
71	9	17	106	25′	4	3.5	19	...	21	...
71A	9	17	106	30′	4	3.5	18	...	19	...
72	9	17	106	53′	8	7.5	3	...	3	...
73	9	17	106	5′	4	3.5	4	...	5	...
74	3	18	107	42′	4	3	32	...	34	...
75	33	19	107	85′	44	3.5	11	...	11	...
76	33	19	107	6′	4	3.5	8	...	9	...
77	33	19	107	20′	4	3.5	15	...	18	...
78	33	19	107	2′	4	3	29	...	36	...
78A	33	19	107	...	4	2.5	57	...	63	...

No.	Location			Thickness	Wt. of Shale, Oz.	Ash Oz. approx	Oil per ton	NH_4 SO_4 Lbs.	Dry base, Gals.	Specific Gravity
	Sec.	T-N	R-W							
79	33	19	107	35′	4	3.5	7	....	8	....
80	15	18	107	....	4	3.5	27	....	30	....
81	15	18	107	....	4	3.	34	....	39	....
82	15	18	107	....	4	3.5	21	....	24	....
83	15	18	107	....	4	3.5	17	....	19	....
84	15	18	107	....	4	3.5	21	....	23	....
85	15	18	107	....	4	3.5	34	....	23	....
86	15	18	107	10′	4	3.5	21	....	29	....
87	15	18	107	2′	4	3.5	25	....	56	....
88	15	18	107	8″	4	3.	53	....	83	....
89	15	18	107	2′	4	2.5	76	....	11	....
90	15	18	107	2″	4	3.5	11	....	16	....
91	15	18	107	2′	4	3.5	15	....	13	....
92	9	18	107	15′	4	3.5	13	....	21	....
93	9	18	107	5′	4	3.5	19	....	22	....
93A	9	18	107	5′	4	3.5	21	....	7	....
94	9	18	107	25′	4	3.5	6	....	18	....
95	9	18	107	2′	4	3.5	17	....	21	....
96	4	18	107	25′	4	3.5	19	....	22	....
96A	4	18	107	2′	4	3.5	17	....	19	....
97	4	18	107	21′	4	3.5	23	....	26	....
98	4	18	107	28′	4	3.5	11	....	11	....
99	4	18	107	10′	4	3.5	6	....	7	....
100	4	18	107	....	4	3.5	11	....	11	....
101	4	18	107	27′	4	3.5	17	....	19	....
101A	4	18	107	5′	4	3.5	29	....	33	....
102	4	18	107	25′	4	3.5	7	....	8	....
103	4	18	107	....	4	3.5	34	....	37	....
107	36	16	108	5′ 3″	....	....	21	5.69	....	.9022
108	36	16	108	6′	....	....	13	5.06	....	.8925
109	17	17	106	5′ 9″	....	....	11	5.51	....	.8798
110	17	17	106	6′ 3″	....	....	19	9.82	....	.9190
111	17	17	106	5′ 4″	....	....	19	8.81	....	.9111
112	17	17	106	5′ 1″	....	....	9	7.59	....	.9075
113	17	17	106	5′ 3″	....	....	10	5.10	....	.9050
114	17	17	106	4′ 6″	....	....	11	3.86	....	.9143
115	17	17	106	4′ 6″	....	....	9	2.28	....	.8848
116	17	17	106	4′ 10″	....	....	4	3.02	....	....
117	27	16	106	8′ 1″	....	....	19	8.68	....	.9903
118	27	16	106	5′ 6″	....	....	14	5.50	....	.9120
119	19	17	106	5′	....	....	12	7.17	....	.8963
120	19	17	106	5′	....	....	14	7.93	....	.8702
121	16	17	106	4″	....	....	14	11.19	....	.9456
122	9	17	106	7′ 3″	....	....	14	4.27	....	.9077
123	9	17	106	6′ 6″	....	....	19	2.74	....	.9197
124	8	18	107	5′ 9″	....	....	13	5.80	....	.9027
125	8	18	107	3′ 3½″	....	....	6	3.73	....	.8800
126	8	18	107	1′ 8″	....	....	29	11.71	....	.9182
127	24	18	107	6′ 3″	....	....	18	7.27	....	.9148
128	24	18	107	2′ 4″	....	....	7	5.65	....	.8862
129	5	21	107	1′ 7″	....	....	8	.69	....	.8705
130	5	21	107	5′	....	....	10	.86	....	.8837
131	5	21	107	2′	....	....	50	1 99	....	.8889



SECTIONS OF GREEN RIVER FORMATION, SOUTHWESTERN WYO
SHOWING POSITION AND THICKNESS OF OIL-BEARING SHALE. LETTERS AT BOTTOM OF SECTIONS REFER TO LOCATIONS

FIGURE 7.

The following table give the amount of gas in cubic feet per ton of shale contained in some of the samples described above:

Sample:	*Gas in cubic feet per ton of shale:*
Letter A	1,365
Number 5	789
Number 8	4,626
Number 9	571
Number 20	546
Number 23	2,316
Number 24	844
Number 27	716
Number 29	4,926
Number 30	2,376
Number 31-A	1,334
Number 32	2,304
Number 33	1,194
Number 34	4,372
Number 35	1,800
Number 36	1,200
Number 37	2,362

The writer believes that a number of favorable conditions must prevail for the successful operation of an oil shale plant. The shale beds must be rich in oil, containing not less than 35 gallons of oil per ton of shale, thick and with little cover so that the shale can be mined with a steam shovel. The plant must be located on or near a railroad and at a place where plenty of water is available. It will necessitate the expenditure of a large amount of capital for big plants so that the oil and by-products can be produced on a large scale. Small plants will undoubtedly be unprofitable. The writer believes that a plant could be successfully operated in the vicinity of Green River station, but that is about the only place in southwestern Wyoming where conditions are at all favorable for the location of a plant.

LOCATION AND VERTICAL SECTIONS

Section A, measured in N. E., one-fourth of Sec. 10, T. 21. N., R. 105 W., on the east side of White Mountains.

Section B, measured near the west line of Sec. 9, T. 17 N., R. 106 W., on Green River.

Section C, measured in Sec. 6, on the south line, T. 17 N., R. 106 W., on Green River.

Section D, measured in Sec. 14, T. 18 N., R. 106 W., base of the section is bottom of creek near the Kanda pumping plant.

Section E, measured in Sec. 33, T. 19 N., R. 107 W., at old prospect entry, entry running N. 28o E.

Section F, measured in Sec. 3, T. 18, N., R. 107 W., about two miles north of Green River City, Wyoming.

Section G, measured in Sec. 9, T. 18 N., R. 107 W., on Green river, base of section waters edge.

Section H, measured in N. W. one-fourth of Sec. 15, T. 18 N., R. 107 W. Base of section waters edge.

Section I, measured in N. W., one-fourth of Sec. 22, T. 18 N., R. 107 W., in Green river City, base of section railroad track 300 feet west of water tank.

Section J, measured in Sec. 28, T. 18 N., R. 107 W., in canyon west of Green river on east side of road to Black's Fork.

Section K, measured in Sec. 5, T. 14 N., R. 108 W., on Green river at Johnson ranch.

Section L, measured in N. E. quarter of Sec. 23, T. 19 N., R. 118 W., on Sheep Creek on the north side of the stream.

DECLINE CURVE PREDICTION FROM FIRST DAY AND FIRST THIRTY DAYS

Glenn H. Alvey

At present one is unable to appraise an oil well scientifically until the decline curve is known, the use of which requires a knowledge of the first year's production. The discovery clause of the Income Tax Law, as now interpreted, makes it very important, however, that the future of a well be predicted at the end of the first day or of the first thirty days thereafter. This paper is offered as a beginning toward the gathering of such data as will permit the solution of this problem.

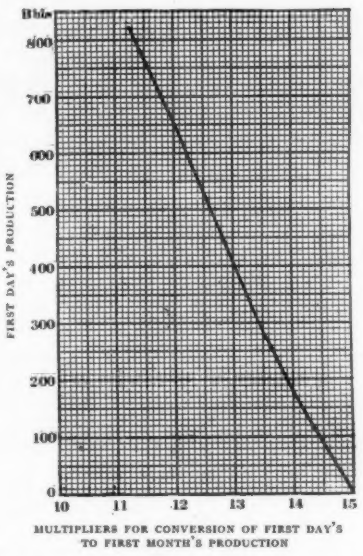


Figure 1. Curve showing the relation of first day's production to that of first month, Washington and Cameron districts, Pa.

Glenn H. Alvey.

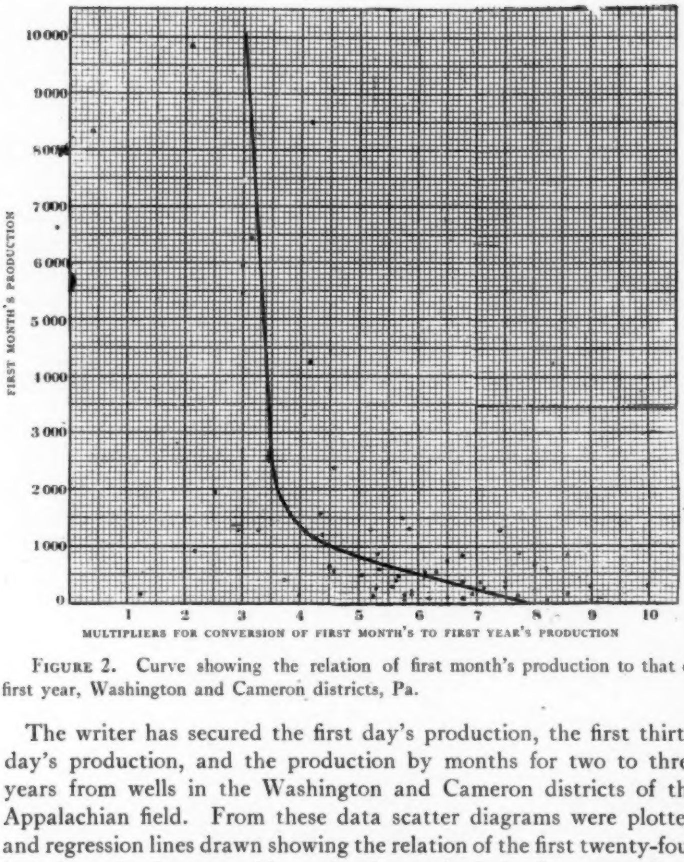


FIGURE 2. Curve showing the relation of first month's production to that of first year, Washington and Cameron districts, Pa.

The writer has secured the first day's production, the first thirty day's production, and the production by months for two to three years from wells in the Washington and Cameron districts of the Appalachian field. From these data scatter diagrams were plotted and regression lines drawn showing the relation of the first twenty-four hours' to the first month's production and of the first month's to the first year's production. (See Figures 1 and 2.)

The first of these graphs gives the multipliers by which the first day's production for wells of different sizes can be converted into first month's production. The second gives the multipliers for converting the first month's production into the first year's production. From these it was found that by the end of the first month, for small wells (below 100 bbls.) the daily average

production had declined to one-half of the initial daily production, and for larger wells (1,000 bbls.) it had declined to one-third. By the end of the first year the average monthly production of small wells (1,000 bbls. per month) had fallen off to one-half of first month's production and of larger wells to about one-third.

A graph which is more easily constructed and better adapted to appraisal work is one from which the production is read direct.

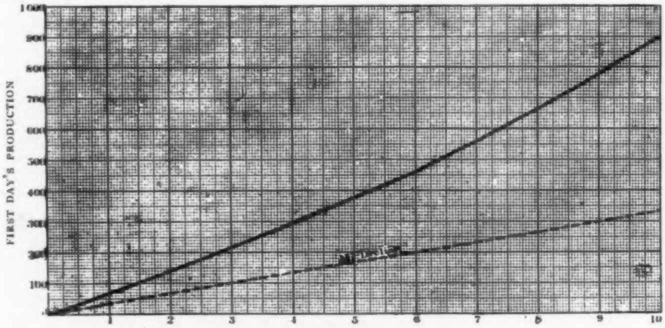


FIGURE 3. Relation of first day's production to first month's production, Washington and Cameron, Pa.

In Figure 3 the first day's production for each well is plotted against the first month's production. A smooth curve is drawn through the mean of these points. Values taken from this curve represent what the average well would produce. Given the first twenty-four hours'

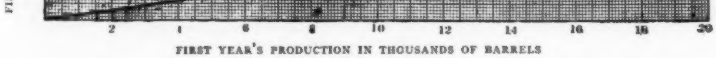


FIGURE 4. Relation of first month's production to first year's production, Washington and Cameron, Pa.

production of a well the first thirty days' production may be read direct. A similar graph (Figure 4) was made for determining the first year's production from the first thirty days' production.

In Figure 5 a direct method of estimating the first year's production from that of the first twenty-four hours' is given. This diagram is made on the same principle as the others. Curves for New Straitsville, Ohio, and Lawrence county, Illinois,[1] are included on the graph. The three curves agree fairly well, but differ enough to show the desirability of having a special curve for every field and every pool where possible.

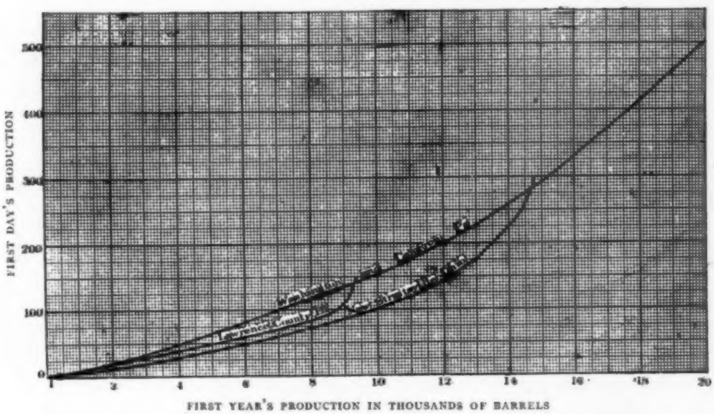


FIGURE 5. Relation of first day's production to first year's production. (Data for Lawrence County and New Straitsville from U. S. Bureau of Mines, Bull. 177).

Something more than the record of the first year's production, however, is desired if appraisal of a discovery well is to be made. One must know the second, third, fourth, and subsequent year's production of the well's life. If only the first, second, and third year's production are known, however, the future production can be fairly well predicted by hyperbolic extrapolation. Using production data from the same wells used in making the previous charts, Figure 6 was constructed. Data for this graph came from three localities:

[1]Beal, Carl H.: The decline and ultimate production of oil wells with notes on the valuation of oil properties, U. S. Bureau Mines, Bul. 177, pp. 60-61, 1918.

Washington, Pa., Cameron, Pa., and Cameron, W. Va., records from the last named being in decided minority. The first month's production was plotted against first, second, and third year's production, different symbols being used for each year. Two smooth lines were drawn so as to include all points for the first year's production. These are respectively the maximum and minimum curves. An average curve was drawn so as to represent the mean between them. The same was done for the second and third years. In order to make the graph more exact, different symbols were used for the different districts represented, so that, for any one of the districts, it is possible to determine from the distribution of the symbols whether the maximum, minimum or average curves should be used. For example, given a well in the Washington, Pa. district, the first year's production for that district is represented by an "o". From the graph it is observed that most of the "o"s lie between the maximum and average curves. Therefore, for the best results a curve for the given well should be drawn between these two. The second and third years are handled in like manner. In the original graph account was also taken of the sands from which production was obtained, but inasmuch as this did not change the results, for the sake of simplicity no separation by sands was made. Figure 6 shows clearly the extraordinarily wide variation in the second year's production of different wells in these districts, and also their very

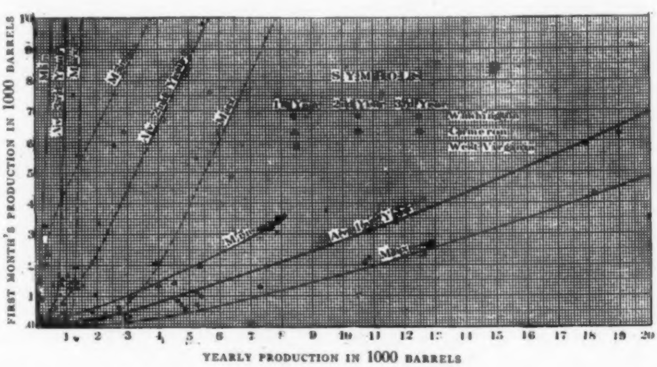


FIGURE 6. Curves showing average, maximum and minimum for first, second and third year in relation to first month's production.

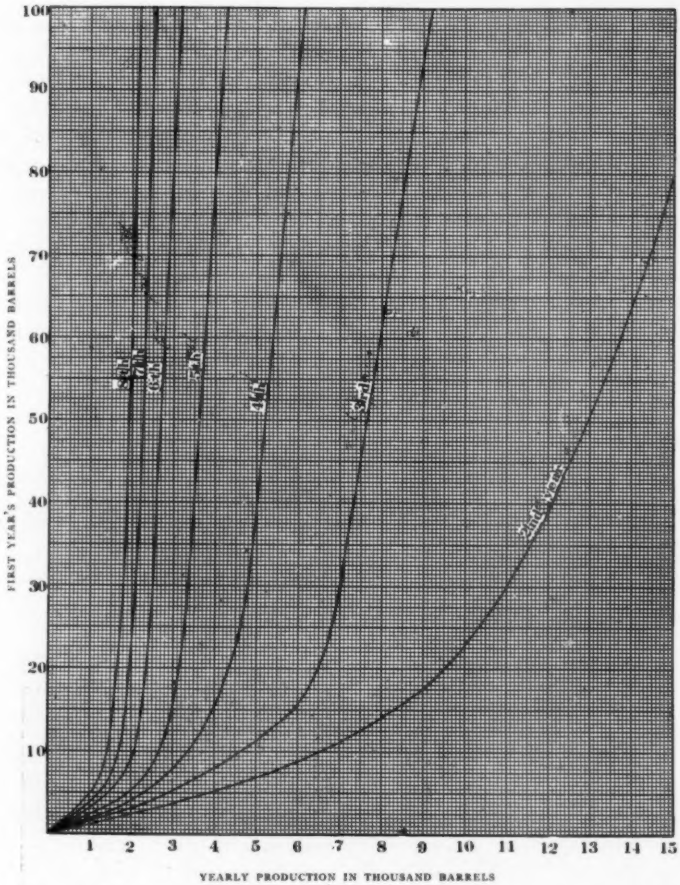


FIGURE 7. Relation of first year's production to subsequent years' production for the eastern part of the Osage Nation. (Data from U. S. Bureau of Mines, Bull. 177).

rapid average decline during the second year. This was unexpected in pools of the Appalachian field. It certainly cannot be taken as the typical yearly decline of the average oil well.

In Figure 7, some of Beal's[2] data are expressed by a method similar to that used in Figure 6, in order to make it more usable for discovery appraisals. Given the first year's production, the subsequent years' production may be read directly from this diagram.

If a record of the first twenty-four hours' production of the first month's production is available, a fairly accurate prediction of the first year's production may be made from Figures 4 and 5. Then the production of future years may be estimated from such a chart as Figure 6. With this material any analytical appraisal may be made.

Monthly decline curves for a number of representative wells were drawn on quadrille paper. These were smoothed and then plotted on logarithmic paper (Figure 8). On logarithmic paper an hyperbola is a straight line. As shown by the diagram, the month decline curves are in most cases nearly straight lines, which shows that the monthly decline curve tends to be hyperbolic. This tends to sub-

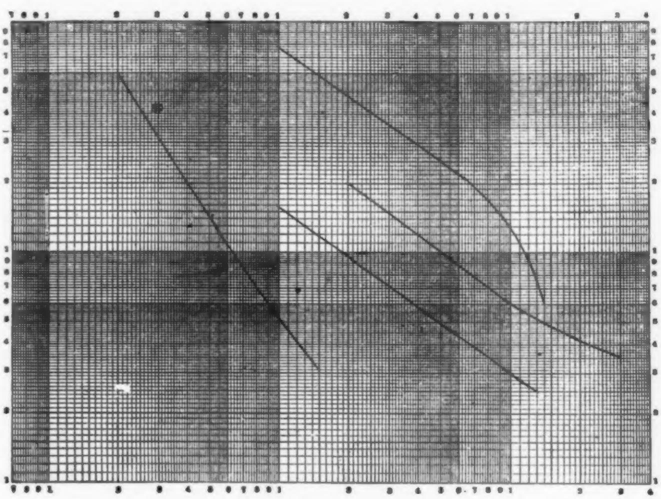


FIGURE 8. Monthly decline curves for typical wells in Washington and Cameron, Pa.

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[2]Beal, Carl H.: Loc. cit., p. 102.

stantiate the hypothesis that oil well decline curves tend to be hyperbolic no matter what the unit of time chosen.

These graphs are not accurate for pools other than the one to which they apply. If no other data are vailable, they may be used for other pools, but account must be taken of the large probable error. Material from which curves for other pools could be made was not at hand. The fact that few companies keep monthly production records of individual wells is a difficulty in securing data. The method here presented is, however, simple, and one can make his own curves for any pool or field in which appraisals are to be made.